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EFFECTS OF ENVIRONMENTAL STRESS ON LAYING HENS AND ITS RELATION TO THEIR WELFARE

GEVOLGEN VAN OMGEVINGSSTRESS VOOR LEGHENNEN IN RELATIE TOT HUN WELZIJN

By

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As you sow
so will you reap

March, 1990

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GEVOLGEN VAN STRESS VOOR LEGHENNEN

IN RELATIE TOT HUN WELZIJN

Samenvatting en besluiten

In onderhavige studie worden twee soorten stress onderzocht. In een eerste faze wordt het effect op de kippen beoordeeld van geluid veroorzaakt door een voederinstallatie en een snelweg.

Waarnemingen werden uitgevoerd met betrekking tot drie groepen legkippen met een aanvangsleeftijd van 20 weken. De eerste groep werd beschouwd als controle, terwijl de tweede en derde groep respectievelijk werden onderworpen aan geluid van een voederinstallatie en van een snelweg. Het geluid van de voederinstallatie werd aangezet gelijktijdig met de voederperiode; het snelweggeluid daarentegen werd overdag met tussenpauzen van 2 uur en telkens gedurende 2 uur opgelegd. Het geluidsniveau van de voederinstallatie en de snelweg bereikte respectievelijk 85 en 95 dB.

Uit de waarnemingen blijkt duidelijk dat stress veroorzaakt door het geluid van de snelweg de produktie van de derde groep legkippen beïnvloedde. Wanneer de intensiteit werd verhoogd tot 95 dB, werd een sterke afname in de produktie van eieren waargenomen; een positieve correlatie tussen geluidsniveau en produktie werd vastgesteld. Het effect van geluid liet zich ook vertalen in een toenemende sterfte en een stijgend aantal eieren in te lage gewichtsklassen. Het geluid van de voederinstallatie beïnvloedde de produktie van eieren door de tweede groep legkippen niet; de voederopname, het aantal te lichte eieren en het sterftecijfer stegen anderzijds wel in vergelijking met de controlegroep.

Het onderzoek wijst uit dat de eierkwaliteit wel beïnvloed werd door geluid van de snelweg, maar niet door het geluid veroorzaakt door de voederinstallatie. Beide geluidsbronnen veroorzaakten evenwel een toenemend aantal eieren met bloed- en vleesstippen.

De gedragingen van de kippen werden geobserveerd met behulp van een video-installatie. Drastische veranderingen in het gedrag van de legkippen als gevolg van geluidsstress werden waargenomen. De meest terugkerende effecten waren paniek en het proberen vluchten doorheen het traliewerk van de deuren van de hokken. Tevens

Het doel van de tweede onderzoeksfaze was de evaluatie van het effect van de voedertroglengte per hen (door de Commissie van de Europese Gemeenschappen wordt 10 cm/legkip aanbevolen) op de karakteristieken van de produktie. Een bijzonder experiment werd opgezet teneinde te kunnen vaststellen of de vooropgestelde troglengte van 10 cm/hen - in vergelijking tot alternatieven - voldoende is om het welzijn van de kippen te verzekeren. Dit experiment was tevens bedoeld om een geschikte troglengte af te leiden, daarbij rekening houdend met zowel welzijnsaspecten als economische factoren.

In de tweede faze werden in totaal 262 volwassen legkippen gebruikt. Vier 'behandelingen' werden gevolgd: 5 dieren per hok met 10 of 12 cm voedertroglengte per dier voor de eerste twee sets, en 4 en 3 kippen per hok met respectieve troglengten van 12,5 en 13,3 cm/hen voor de overige twee sets. De eerste behandeling was gekenmerkt door een bezetting overeenkomstig een vloeroppervlakte van 422 cm^2/dier; in de andere sets was 506 cm^2/dier beschikbaar.

Met toenemende troglengte stegen de produktie, het voederverbruik, de gewichtsaanwinst en de voederconversie, terwijl een daling werd genoteerd voor de factoren sterfte, vederbeschadiging en het aantal gebroken en bevuilde eieren. De troglengte had vooral invloed op het voorkomen van agonistisch en abnormaal gedrag onder de vorm van vederpikken en duwen. Significante verschillen werden gevonden in het gedrag, het produktieniveau en de bevedering van de dieren. Al deze effecten verdwenen slechts wanneer een voldoende grote troglengte beschikbaar was. Nochtans werd vastegesteld dat een troglengte van 13,3 cm/dier nadelig was; vermoedelijk omdat deze lengte groter is dan die waaraan de dieren werkelijk behoefte hebben. Ter ondersteuning van dit vermoeden werd geregistreerd dat dieren in hokken met 13,3 cm troglengte per dier een hoger corticosterongehalte vertoonden dan de dieren in alle andere behandelingen, zelfs in de set waar slechts 10 cm/dier beschikbaar was.

De bekomen resultaten wijzen erop dat tussen de vier groepen geen significante verschillen voorkomen in misvormingen of dikte van de eierschaal. Niettemin werden belangrijke gradaties in het eiergewicht en in voorkomen van bloed- en vleesstippen vastgesteld.

Uiteindelijk werd de conclusie geformuleerd dat, met betrekking tot economie en dierlijk welzijn, een voedertroglengte van 10 cm/dier onvoldoende was voor legkippen. De auteur stelt voor om in de toekomst een troglengte van12 cm/dier te hanteren als meest economisch en voor de dieren meest komfortabel alternatief.

werden gevechten vastgesteld; deze eindigden soms in hysterie en kannibalisme. Geluidsoverlast lag aan de basis van een verminderde frequentie van het komfort- en onderhoudsgedrag, en leidde tot agonistisch en abnormaal gedrag.

De auteur wijst erop dat gedragsanalyse geschikte aanduidingen levert in verband met het welzijn van de kippen; dit soort tests biedt bovendien duidelijke correlaties met andere komfortindicatoren. Vastgesteld werd dat de gedragingen van de dieren beïnvloed werden door de daglengte.

Een bijzondere nadruk werd gelegd op het economisch aspect van de produktie, waar veel schade optrad als gevolg van geluidsoverlast. In onderhavige studie worden de produktiekosten vergeleken tussen de controlegroep en de groepen onderworpen aan specifieke geluidsstress. Het bleek dat dit laatste fenomeen aanleiding gaf tot sterfte, te laag eigewicht, toenemend aantal gebroken en bevuilde eieren en tot hogere voederkosten.

Aandacht werd besteed aan de minerale samenstelling van de eierschaal. De gegevens wijzen uit dat het geluid van de snelweg het gehalte aan calcium, magnesium en fosfaten in de eierschaal wijzigde. Met betrekking tot het geluid van de voederinstallatie werd enkel een verandering van het percentage magnesium vastgesteld. Geluidsstress veroorzaakte een degradatie van de bevedering op verschillende lichaamsdelen van de kippen. In dit verband moet het ongewenst karakter van allerhande geluidsbronnen binnenin (b.v. verwekt door het aanvullen van de voedervoorraad) en in de omgeving van de legkippenstal (b.v. snelwegen) worden benadrukt.

Naast het afbreuk doen aan de gelijkmatige bevedering, induceerde een overmatig geluidsniveau tevens een stijging van de corticosteron-concentratie in het bloedplasma van de dieren. Een positieve correlatie werd vastgesteld tussen de concentratie aan corticosteron in het plasma en (a) de verschillende geluidsniveaus, en (b) het ogenblik van blootstelling van de dieren aan het geluid. Zowel het geluid van de snelweg als dat van de voederinstallatie vormden een oorzaak van het optreden van een groot aantal afwijkingen in de eierschaal. Een relatie tussen de verschillende geluidsintensiteiten en misvormingen van de eierschaal werd bewezen. De daglengte beïnvloedde het voorkomen van abnormale eierschalen.

Onze resultaten kunnen de basis vormen van een pijnloze, snelle en betrouwbare methode voor het beoordelen van de aanwezigheid van stress bij legkippen, en dit via analyse van de minerale samenstelling van de eierschaal enerzijds, en het registreren van afwijkingen aan de eieren anderzijds.

ABSTRACT

In the present study two types of stress are examined. The first phase of investigations was conducted to evaluate the effect of noise generated by a feeding machine and a highway on laying hens caged in batteries.

Observations were carried out on three groups of laying hens aged 20 weeks. The first group of hens was considered as control whereas the second and the third groups were subjected to feeding machine and highway noise respectively. The feeding machine noise was activated concurrent with the feeding time, and the highway noise was activated intermittently (2 hr on : 2 hr off) during the day time. Noise level of the feeding machine and highway reached a maximum decibel reading of 85 and 95 respectively.

From observations made in this study it is apparent that highway noise stress had clearly affected the production performance of the third group of laying hens. Noise intensity was increased to 95 dB, causing greater decline in egg production and a positive relation between noise intensity and egg production was established. This group consumed more food than the control group. The influence of noise was also registered through the increased percentage of mortality and undergrade eggs. There was no detrimental effect of the feeding machine noise on egg production in the second group of laying hens. However, feed intake, undergrade eggs and mortality, were all increased by comparison with the control group.

Results of our investigation show that egg quality was influenced by highway noise but not by the feeding machine noise. Eggs from hens exposed to the feeding machine and highway noise had increased blood and meat spot incidence.

Behavioural activities of the hens were recorded using video equipment. Drastic effects were noticed in connection with noise of both feeding machine and highway on the laying hens. Most commonly observed were panic and flight through the bars of the cage door, or fights sometimes ending in hysteria or cannibalism. Noise stress caused a decrease in comfortable and maintenance behaviour and increase in agonistic and abnormal behaviour.

The author summarizes his opinion that behavioural tests seem the most appropriate indicators for the welfare of the laying hens ; they are also related to other indicators. It was noticed that behavioural activities were affected by the length of day.

Much more emphasis is placed on the economic trait which was damaged by the noise. The study compares egg production costs in the control group with the groups exposed to noise. It was noticed that noise induced a decline of the egg profits, the main direct causes being mortality, undergrade eggs, including broken and dirty eggs, and feed cost.

The study also gives attention to the mineral contents of the egg shell. The data indicated that highway noise affected the percentage of the calcium, magnesium and phosphate in the egg shell. In the case of feeding machine noise, magnesium was the only mineral which was affected. Noise stress influenced the degree of feathering deterioration on various parts of the hens' bodies. Indeed, the extent of feather damage evidence warrants criticism of the noise produced by the installation inside the poultry house as well as outside noise as generated by a highway or by any other activities, like the filling of the feed bin.

The experiments have shown that noise, in addition to causing feather damage, induces an increase in corticosterone concentration. A positive correlation was observed between corticosterone concentration in the plasma and (a) the various noise intensities and (b) the period of exposure to the feeding machine noise. The noise of the feeding machine and highway gave rise to a lot of abnormalities in the egg shell. Evidence was found of a relationship between various highway noise levels on the one hand and egg shell malformation on the other hand. It was observed that the length of day influenced the incidence of abnormal egg shells.

Our results may provide a basis for a non-painful, quick and reliable method of determining stress in laying hens by analysing the mineral contents of the egg shell and by recording the incidence of abnormality in eggs.

The aim of the second phase of the investigation reported here was to explore the effect of feeder length per hen (the European Commission recommends a length of 10 cm/hen) on variables associated with laying hen performance. In particular the study was set up to ascertain whether a feeder length of 10 cm/hen ensures adequate hen welfare as compared to other designs, and to point out a suitable feeder length for hens under given welfare and economic considerations.

A total of 262 adult hens were used in this phase. Four 'treatments' were observed: 5 hens per cage with either 10 cm or 12 cm feeder length per hen in the first two objects, and 4 and 3 hens/cage with respective feeder lengths of 12.5 and 13.3 cm/hen for the last two objects. The first treatment had a density of 450 cm^2/hen, while the other treatment had 506 cm^2/hen.

As the feeder length increased, egg production, feed consumption, weight gain and feed conversion were all higher, whereas mortality, feather damage and dirty as well as broken egg levels were lower. Feeder length mainly influenced the number of incidences of agonistic and abnormal behaviour by increasing feather pecking and pushing. Significant differences in behaviour, production performance and plumage condition were observed. These traits were improved only when feeder length increased. However, it was observed that increasing feeder length up to 13.3 cm/hen caused negative influence, probably because this length is more than the hens actually need. As evidence to support this assumption, it was noticed that hens in cages with 13.3 cm/hen feeder length had higher corticosterone concentration than those in any other treatment, even with 10 cm feeder length/hen.

The obtained results indicate that no significant difference in shell deformation and thickness occurred between the four groups. However, the traits of egg weight, blood and meat spots were significant.

Finally, from the point of view of economy and hen welfare, both a feeder length of 10 cm/hen and a surface area of 450 cm^2 were inadequate for laying hens. The latter conclusion has been drawn earlier by DAWKINS and HARDIE (1989).
The present author concludes that a cage with 5 hens offering a feeder length of 12 cm/hen and a surface area of 506 cm^2 is appropriate for the laying hen, this feeder length and surface area being both most economic and best for welfare considerations.

INTRODUCTION

Within the last few years, concern about the protection of the environment has grown rapidly as it has become generally recognized that the steady rise in pollution of all kinds cannot be allowed to continue indefinitely.

The acoustic environment has likewise suffered from the increase in the use and power of machines in the work place or animal farms. Increased road traffic, civil or military air craft and other noise sources contribute to noise nuisance.

The influence of various factors on animal welfare and production levels have been well studied to a great extent because they are related to economics. However, the impact of noise has not often been considered critical. Yet, if one was to isolate the different sources of noise on the farm, sound levels are likely to be significant even without this farm being situated in a particular noisy environment such as near a military airport or a highway. Adding up noise levels produced by the technology available on the farm such as feeding machines or cleaning activities or the operation of extractor fans (these we call 'sudden noises'). It is obvious that an excessive sound level may be reached which could be harmful to the animal and consequently jeopardize the cost effectiveness of the whole production system.

To our knowledge no publication is available dealing with the influence of noise stress produced by feeding machines on laying hens. Behavioural studies are another method of assessing what is happening to animals. The fowl is a well studied species, that the amount we know about its behaviour is inadequate for an understanding of it. Often the information dealing with the influence of noise stress, produced by feeding machines on laying hens welfare does not exist. There is clearly a need for further investigation to determine the extent to which hens are stressed due to noise emanating from feeding machines. Poultry stress will be assessed by physiological responses using corticosterone levels in the blood as physiological indicator for stress and behavioural responses, egg quality, abnormalities of egg shell, feather condition, production and minerals content of the egg shell. At present, interest in the above topic is high, as scientists are constantly trying to improve animal welfare.

Only a brief Japanese study that dealt with the effect of noise on the mineral contents of the egg shell in hens has been available. The authors (KAZUSHI and SUGAWARE, 1986) recommended further research in this field as they used only small numbers of experimental units. There is a necessity to get to know more about the effect of noise on the minerals content of egg shell in hens.

Floor and feeder length are major factors in reduced profits for the egg industry. Overcrowding and cage design affect the plumage of birds, extensive feather damage being a significant economic and welfare concern. It is generally accepted that a feeder length of 10 cm per bird is sufficient for production and economic purposes only, without making a judgement about the well-being of laying hens. This part of the study was conducted to determine whether the well-being of laying hens is influenced by feeder length, and to decide which length is appropriate for production, welfare and economics behind the production process.

Eventually, two types of stress have been considered in this study, i.e. feeder length and the noise of feeding machines and a highway. It is possible to compare between the stressors and to evaluate the importance of welfare for the hens, and those stressors have been identified which typically occur on farm production units.

The purpose of this study was to evaluate the influence of stress on laying hens, by employing various indicators of welfare. The indicators of welfare included productivity, behaviour, physiology, feather coverage, egg quality and chemical composition of the egg shell.

The present thesis contains several separate studies each dealing with animal welfare. Chapter one contains a critical literature review. A brief coverage of the sensory abilities of the hen is given first, with examples of how sensory inputs are important in the life of a hen and hence how knowledge of their abilities is essential for understanding the effect of the environment on the hens. Some of the accumulated knowledge pertaining to the different kinds of noise shows how noise affects the birds and the animals. A third major section deals with animal welfare and the various methods for assessing it. Chapter two contains a description of the materials and methods employed in the study.

The third chapter consists of the obtained results. The first set of experiments deals with the effect of highway and feeding machine noise stress on laying hens ; its relation to animal welfare is judged and the results are compared with the control. Trough length is shown to affect the hens' feeding behaviour and feather loss; it may also affect the welfare of the layers in the cages. Egg shell classification is used as a measure of stress on laying hens. The results are discussed in chapter four. Finally, the conclusions and recommandations are given in chapter five.

1. LITERATURE REVIEW

1.1. The hen's senses

Like other species the fowl is capable of detecting and responding to events in its environment; however, the responses that have evolved as appropriate in natural environments may no longer be appropriate under intensive management. This is because intensive environments are protective in many ways, but at the same time may lack stimulation for birds. Intensive environments intrude into every aspect of an animal's life. Consequently, humans have taken on the responsability of providing suitable places for them to live.

1.1.1. Sight

The importance of the visual sense in the fowl is indicated by the remarkable size of the eyes in comparison with the size of the head and brain. Thus the weight ratio of the two eyes to the brain is almost 1 to 1, while in man the corresponding ratio is 1 to 25 (KILGOUR and DALTON, 1984). Detailed descriptions and comparisons of the structure of the avian eye may be found in the work of FRANTZ (1939).

Sight is particularly important and is well developed in most species of birds. Hens have binocular colour vision with a maximum spectral sensitivity similar to man's, except for a reduced sensitivity to blue light (PRESTON, 1983). Colour vision is good (PUMPHREY, 1948), sizes and shapes are discriminated using depth cues (FANTZ, 1959). Intensity discrimination in birds may be considerably poorer than colour discrimination, as is suggested by the fact that birds are more readily trained to distinguish colours (MENTZER, 1966).

Vision is important in almost every aspect of poultry life. For example, hens awake easily in the morning, as soon as it is light, and actively involve themselves locating food and selecting particles for consumption. Finding and selecting food, as well as picking up small particles with the beak, require a high level of visual accuracy (PRESTON, 1983). The relation between lighting and egg production has been studied from the economic point of view (MORRIS, 1961); increasing the illumination from 0.2 to 0.3 lx increases egg production by about 10 %. Abnormal lighting conditions may have remarkable effects on eye development; for instance, rearing in dim red light causes a 50 % increase in eye weight together with considerable short-sightedness (HARRISON and McGINNIS, 1967), whilst rearing in continuous light causes swelling of the eye, long-sightedness and blindness within 24 months of age (LAUBER and McGINNIS, 1966).

SCHUMAIER et al. (1968) found that the wave length as well as the intensity of light may affect the amount of undesirable behaviours such as feather pecking.

Fowl are highly social animals and there is plenty of evidence that vision is important for bird spacing (McBRIDE, 1975). In addition, CRAIG and GUHL (1969) have shown that physical orientation is related to status for floor birds. In cages the case may be different and only the heads may be involved in visual spacing since the bodies of the birds are often unavoidably in contact.

HUGHES (1975) positively related space to bird welfare by showing that a spacious cage was preferred over a small one regardless of strain of layer or time of day, although DAWKINS (1981) indicated that the hens choose a small cage with litter rather than a larger one with no litter and a wire floor. It is unclear in the latter case which sense was of prime importance although the assumption that it was the tactile one has been made. However, visual and olfactory cues might also be involved. Experiments limiting sensory inputs available in choice situations, for example by blindfolding, might clarify this (McFARLAND, 1981).

1.1.2. Hearing

The structure of the bird's ear differs from that of the mammalian ear in a number of interesting aspects, particularly in the middle and inner ear. The outer ear is notable for the lack of the pinna found in mammals (VON BEKESY, 1960). For further reviews see also PEARSON (1972).

Hearing is involved in a wide range of the fowl's activities. For instance, the repetitive clucking by the mother hen aids to keep her in contact with her brood, particularly when vision is limited (FISHER, 1972). Hens have a range of calls that are exhibited in different situations and which have specific functions. Alarm calls warn about the type and location of predators, crowing may allow the recognition of individuals the auditory marking of territories. Prelaying calls may serve to attract attention or communicate intent (RHEIN, 1983). Birds have cycles or places of activity such as periods of feeding, the egg laying sequence, resting, etc. throughout the day. Many of these may be synchronised by sounds in the surrounding environment, such as the arrival and departure of staff or the starting and stopping of feeders.

Measurements of auditory thresholds in a number of bird species are referred to by SCHWARZKOPF (1968). Unfortunately, the fowl is not included in this list, so the measurements of HEISE (1959) on the pigeon will be considered here as a fairly typical example. One may note that the area of the fowl's ear drum is about 50 % greater than the pigeon's, so that one might expect the fowl's ear to be slightly more sensitive. The most striking of HEISE's results is the rapid fall-off of the pigeon's sensitivity at high frequencies. At 2 - 6 kHz the pigeon's sensitivity was only some 15 dB less than that of human observers and at 4 kHz the difference would probably not have been much greater.

Song-birds have a continuous frequency range of hearing from below 500 Hz up to about 6 kHz, and their sensitivity to sound depends upon its frequency, such that their hearing is generally most acute near 3 - 4 kHz. Although a bird's auditory sensitivity certainly varies across species, some have hearing which is as sensitive as that of human beings (McFARLAND, 1981).

1.1.3. Touch

The tactile sense appears to be well developed in the hen, but systematic experimentation exploring its degree of development is lacking. Sensory receptors are known to exist at the skin surface of the rooster, and Meissner corpusclus, similar to those found in the grasping pads of mammals, are present in the foot (WINKELMAN and MYERS, 1961).

It is easy to see why the tactile sense is important to hens. It is used for body care in scratching and preening, and for "comfort" behaviours, such as dustbathing and stretching. Tactile cues are also involved in feeding, drinking, and the brooding of eggs (PRESTON, 1983).

HUGHES and BLACK (1973) conclude that layers in cages had a tactile preference for standing on wire netting as opposed to other types of metal floors. Their study suggested that simplistic presumptions, in that case wire netting floors, were uncomfortable and ought to be banned.

Caged life is such that hens touch each other and their cage all the time. This continuous contact causes abrasion and presumably the greater the amount and force of contact, the greater the damage to feathering. Tactile input is involved in physical contacts during agonistic encounters and therefore plays a role in determining the social structure of groups of hens.

1.1.4. Smell

The structure of the avian olfactory organ is described by KARE (1965). The sense of smell is probably the least developed of the senses although an olfactory epithelium does exist (FISHER, 1975). The comparative development of the olfactory system in birds is considered by COBB (1960).

Concentration of gases such as ammonia detrimentally affects egg production although it is unclear whether birds become aware of the presence of ammonia through their sense of smell. Ammonia build-ups are caused by poor ventilation, wet deep litter or by dropping piles under the cages, unless these are kept dry. Ammonia levels in closed layer sheds may therefore be a problem. A solution sometimes adopted is to employ mechanical scrapers to remove faeces regularly.

Olfactory discrimination has been demonstrated in the pigeon, whose olfactory development is similar to that of the fowl. This discrimination could be abolished by cutting the olfactory nerve (MICHEALSON, 1959).

1.1.5. Taste

In the chicken, about 24 taste buds are found at the base of the tongue and on the floor of the pharynx. They are innervated by fibres from the gloss opharyngeal nerve. For a comprehensive review of the avian sense of taste the reader may refer to KARE (1965). More work has been done with the chicken than with any other avian form (GENTLE, 1971).

The sense of taste is well developed (GENTLE, 1979). For example, day old chicks can taste and reject faeces. Hens can discriminate between carbohydrates, bitter substances and salt (LINDENMAIER and KARE, 1959), although the exact nature of the discrimination process is not well understood. It is known however, that the hens' taste is more acute in regard to liquids than solids. This is of particular importance in selecting palatable medications or supplements usually provided in drinking water. HUGHES (1979) reviews evidence that birds have or can develop the ability to select various elements in their food and also some vitamins, protein in general, and specifically, for the amino acid methionine. He also states that hens appear able to consistently select a diet that is sufficient, without ever experiencing any severe deficiencies and he suggests that genetic and learned roles affect feeding behaviour. Feathers from spent hens are often recycled in food meals. He questions whether a taste for feathers could be thus developed and somehow associated with the feathers in the hens' environment so that they are encouraged to feather peck. Even if this is not the case, there could be a taste component in activities such as feather pecking.

It should be mentioned that the fowl is very sensitive to the temperature of water. It will tend to reject water that is above the ambient temperature, but will readily drink ice-cold water (KARE, 1965).

1.2. ANIMAL STRESS

To date, animal stress has not been given a universally accepted precise definition. The uses of the term stress are confusingly diverse and a more precise meaning is scientifically desirable. The divergent definitions are, unfortunately, leading to confusion in gathering and integrating available data from the literature (YOUSEF, 1988). The most widespread use of stress is as a dynamic term returning to something happening to an individual. The following definitions are therefore proposed :

Stress	:	the processes by which enviromental factors over-tax control systems in an individual, thus activating responses whose effects are prolonged and ultimately detrimental to that individual (BROOM, 1975).
Stressors	:	the environmental factors which lead to stress.
Stress responses	:	the response to stressors, or their effects, shown by animals under stress.

The word stress is precisely defined in physics. A force applied to a spring either elongates or compresses it. This force is termed "stress" and the resulting relative change of the spring length is described as "strain" (figure 1.1). If the stressing force is too severe, the spring may be lengthened or compressed to a level where it can not return to its original length after the stress is removed. On the other hand, when the term stress is applied to biology, for example, the environment may be stressing, and thus its components either singly or in concert are often called "stressors" (DUNCAN, 1980; YOUSIF, 1988).

Stress in physical terms

Stress/strain relationship

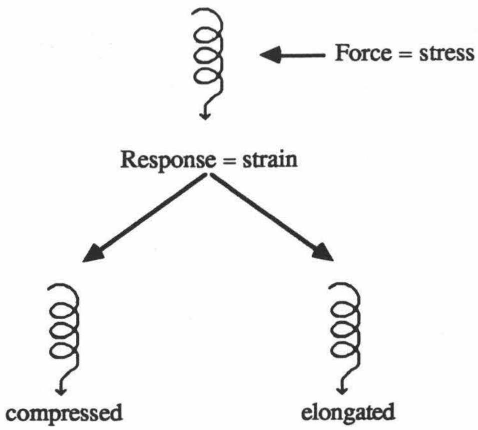


Figure 1.1. A diagrammatic representation of a force and its response on a spring to explain the definitions of stress and strain in physiological terms (YOUSIF, 1988)

The animal exposed to a stressful environment is described as either "stressed" or "strained". The failure of biologists to reach a precise definition of stress has led to the unfortunate expression of animal stress in a negative condition (i.e. reduced efficiency and productivity, reduced fitness, etc.). Nevertheless, available evidence suggests that animal stress should be perceived as a positive influence when it leads to adaptation (McFARLAND, 1981; DUNCAN, 1983 ; YOUSIF, 1988).

To summarize, the stressors which affect an animal may be divided roughly into (a) factors in the physical environment, e.g. nutritional deficiencies, abnormal temperature or humidity; STADELMANN (1958 a,b) has considered noise as a physical stressor in fowls also; (b) factors derived from particular genotype-environmental interactions, for example the chicken is a highly social animal and it is possible that interruption of social behaviour may act as a stressor (BRUCKNER, 1933); and (c) factors operating through the social milieu of the animal. SIEGEL (1961) has made studies revealing that social behaviour may also act as a stressor in adult chickens (feather pecking). Stressors act either on the immature chick or on the adult and primarily affect either behaviour or physiological processes (WOOD-GUSH, 1961).

Most animals are able to cope with environmental disturbance by means of "defensive" behaviour or homeostasis, or result in regulation at a new state of homeostasis (acclimatization) (McFARLAND, 1981). However, there are limits to the animal's capacity to cope with very intense or prolonged disturbances (GRAY, 1971). More recently, McBRIDE (1980) has developed an electric model that allows the welfare of animals to be related to their responses to environmental conditions. The model (figure 1.2) specifies several types of adaptation and provides a declination of animal welfare, since chronic welfare problems are regarded as a failure of animals to adapt to environmental conditions. He indicated that behavioural responses are first used to cope with arousal stimuli.

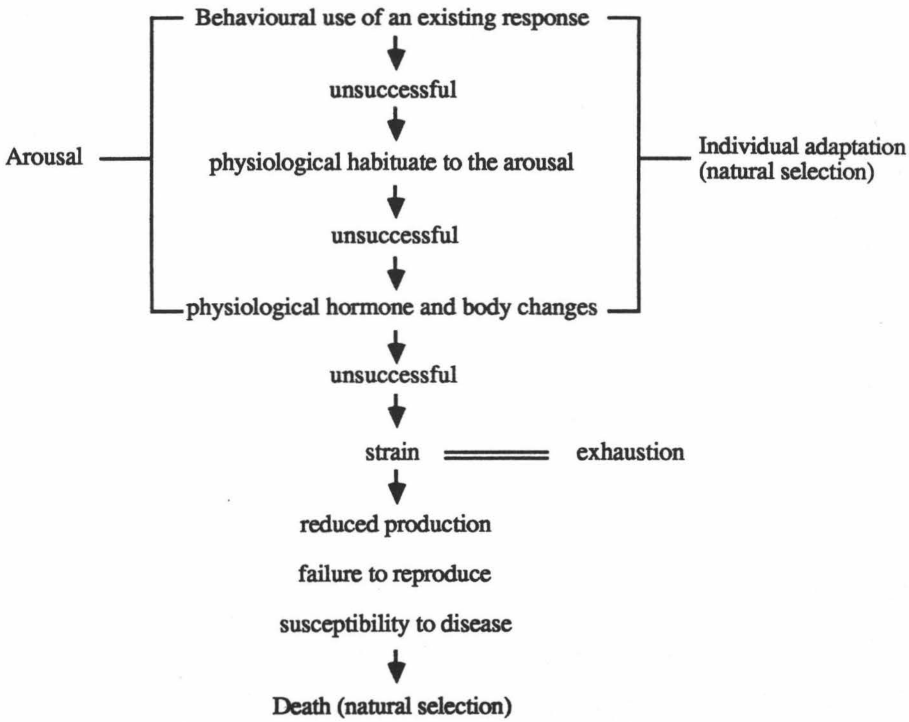


Figure 1.2. Coping with stress (after McBRIDE, 1980)

If not, acclimatization and habituation will provide for a slower term adjustment. The third order coping mechanisms are physiological and involve the "stress" hormones. They also enable the animal to adjust. If these regular mechanisms are insufficient for coping then "welfare" becomes an issue. When the arousal stimuli are such that strain and exhaustion begin, the animal becomes distressed. Production may also be adversely influenced.

In the natural environment, stress may result from physical factors such as sudden storm, flooding, or from encounters with predators, or from social relationships. In captivity, stress can be induced by unnatural conditions. Overcrowding, for instance, may cause animals to be subjected to aggression from which they cannot escape (DANTZER and RAAB, 1985). In the interests of animal welfare, steps are usually taken to avoid these circumstances (McFARLAND, 1981).

Finally, stress can occur in many forms and is difficult to understand. No simple formula or computer program will give us answers to many of the questions which block the path to full understanding of animal stress. To fill the gaps in our knowledge, animal experiments must continue (YOUSIF, 1988).

1.2.1. Noise

Sound, as an environmental factor, has attracted considerable attention in recent years and sound can sometimes be close to noise. Noise can be defined as every undesirable sound which has a negative influence on the health and well-being of one individual or a whole population (World Health Organization, 1980).

The strength or intensity of a sound is expressed on a logarithmic scale as decibels of sound pressure level (dB). Acoustic parameters are expressed as a logarithmic ratio of the measured value to a standard value. This reduces the numbers to manageable proportions and the resulting unit, called the Bel (after Alexander Graham Bell) is defined as the logarithm to the base ten of the ratio of two acoustical powers, or intensities. As this unit was found in practice to be rather too large, a unit of one tenth of a Bel, the decibel, is now in general use. The acoustic intensity, i.e. the power passing through a unit area in space (BRUEL and KJAER, 1979). Our environment has many pollution factors and one of them is noise. Figure 1.3 shows the typical noise level in our daily lives as based on a scientific index, called the noise pressure level (MENTZEL, 1974).

Noise is considered as an environmental pollution in some European community law for protection of nature, with a special paragraph in legislation for animal rights. In certain cases the law of animal protection can be used: it is forbidden to hurt animals without any reason (World Health Organisation, 1980). Some types of information are relevant to the effect of noise on domestic animals, which has been studied.

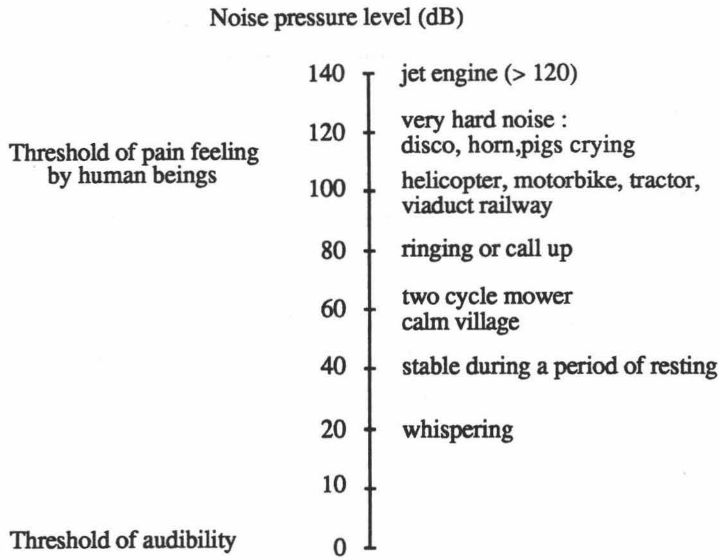


Figure 1.3. Typical noise levels in our day lives (after BODO, 1983)

SCHNELL (1981) found many reasons for sound pollution by civilian planes, for example at starting or when testing the engines. The same is true with military planes, which make a lot of noise (140 dB). WELCH and WELCH (1970) published information, which is currently available, on the effect of sounds upon biological organisms. Most of these studies consider noise as a stress factor and observe the adverse effect on farm animals and other species exposed to sonic booms, military planes or other industrial sources of noise. The expansion of civil and military air bases throughout the world has caused some concern among poultry men with respect to their location in close proximity to poultry production areas (RHEIN, 1983).

Noise from civil and military planes is no doubt a really potential source of health problems. Low level flights, ultrasonic clap from planes (STEPHAN, 1982) and suspension flight of helicopters all lead to a disturbance of the good-health of human beings and frighten animals.

There is reason to accept that noise has an important influence on being stressed, although it is difficult to estimate the extent of the influence on animals. However, the influence on animals depends on the physical characteristics of the sound and on the distance from the source to the animal (GRUNERT, 1983).

1.2.1.1. Effect of noise on brooders

Few investigations are found in literature on the influence of noise on farm animals. Assessing the whole range of effects of noise on domestic birds is complicated, because there are a lot of factors which cause the effects. Such factors include the type of noise, the period of the load, the strain of domestic birds and also the environment of breeding, etc.

In these investigations different tests have been used, and consequently different results about the influence of noise have been recorded. Nevertheless, the results may be comparable.

Ethologists have recently discovered that developing chicks communicate with their mother. The hen's clucks, which provide contact with the embryos, arouse a return twitter, or pleasure call, from the unborn chick. Reciprocal responses to the chick's distress call and the hens' alarm call have also been observed. Such events prior to hatching are part of the emotional attachment process in birds. It is possible, therefore, that incubator hatched chicks, turkey poults, quails and ducklings are socially deprived. It may be feasible to correct some of this deprivation, if proved to exist, in large commercial hatcheries by exposing the embryos to appropriate tape-recorded parental sounds (FRINGES and JUMBER, 1954).

Some of these "supernormal" artificial sounds that produce certain desired behavioural changes in the birds, such as to arouse birds for feeding or to quieten them for handling, might be used more widely in all kinds of set-ups for the husbandry of poultry (CHRISTENSEN and KNIGHT, 1975).

The question remains what effect the noise of passing trains has on the incubation, fertility, or hatchability of hens. BATEMAN (1964) found that the passing of trains had no effect on the incubation, or hatchability of the eggs, provided that it was repeated regularly. That means the fowls probably adapted to such environmental challenge. It is obvious that if an animal is adapting in this sense, it does not mean that there is no threat to or influence on its welfare; indeed, it means almost precisely the opposite. If its welfare is not threatened, then adaptation in this sense would not be necessary.

The above research results were similar to those of STADELMAN (1958), who concluded that there was no negative influence on fertilized eggs inside incubators when exposed to plane noise. However, when cocks were exposed to plane noise, the spermatological research showed that fertilization capacity was decreased. The responses of chickens and swine to simulated aircraft sounds were recorded (BOND et al., 1960 and KOSIN, 1958). These sounds, about 120 dB in intensity and composed of mixed frequencies, did not affect the sperm production in male chickens. However, it did cause a depression in the hatchability of eggs with embryos sired by exposed males.

Investigation conducted under laboratory conditions established that a noise background with a sound pressure level of 90 dB, produced a decrease of 1 - 5 °C in rectal temperature and a sharp drop in skin temperature. The respiration and heart rates rose by 10 and 15 % respectively (OGANESOV, 1978).

1.2.1.2. Influence of noise on laying hens

There is reason to accept that noise has an important effect on the psychological status and productivity of laying hens. A reduction in noise level by only 5 - 7 dB leads to an increase of 2 % in egg production and a drop of 0.1 % in mortality. Therefore, the egg producers should be more aware of the effect of suchlike stress which can affect the farmer's income (BELANOVSKII and OMEL'YANENKO, 1982).

Long term noise (sustained for three days or more) was more likely to decrease productivity than short bursts of acute noise level (HAMM, 1967). In contrast to this, COTTEREAU (1973) claimed that laying hens exposed to 6 simulated supersonic sound claps during a period of 4 months showed no panic and egg production was normal. Egg production is affected by decrease or increase in the sound level. IVOS et al. (1976) showed that egg production had already some decline at 76 dB. Increasing the noise intensity to 128 dB caused an even greater decline in egg production. The experiments indicated that a noise intensity of 83 dB can have a harmful effect on egg production. These results were similar to those recorded on hens which were housed on litter and exposed to bells and sirens with an intensity of 84 - 128 dB for 10 minutes daily. This resulted in a decrease of egg production of between 0.1 and 12.8 % and also in an increased mortality (OMEL'YANENKO and NAIDENSKII, 1976).

Noise stress also affects wild birds. KAWAHARA (1976) found that the egg laying performance decreased in both strains under noise treatment, but the wild strains showed more noticeable depression than the domestic strain. The researcher indicated that the egg production rate of the wild strain decreased by 23 %, while that of the domestic strain decreased by 7.1 %.

White leghorn laying hens appeared to be stimulated by sound at 79 dB and a frequency of 0.5 - 2.0 kHz. When the frequency was increased to 2 - 5 kHz, egg production decreased. Sound at an intensity of 90 dB with a frequency of 0.5 - 2 kHz and 2 - 5 kHz in particular, had a harmful effect on hens (OMEL'YANENKO and NAIDENSKII, 1976). KELLER (1971) used a fire-brigade siren as noise source; his results showed that noise of 83 dB intensity affected egg production adversely. Blood vitamin content was also low in noise stressed hens. The frequency of occurrence of soft-shelled or blood-spotted eggs was not affected by the noise (SEIKAN, 1963).

1.2.1.3. Effect of noise on broiler hens

There is a negative effect of noise on the body weight of the broiler. Results of HAZUSHI and HAKU (1980) indicated that the mean weight of a group loaded with noise was usually below the lower critical limits of body weight of a control group. This is a dramatically different result compared to the situation reported by LEHMAN (1966), whose results showed no difference in body weight between exposed group and control group. However, he found that the hens made escaping movements.

RHEIN (1983) indicated that for broiler chicks there were no effects on feed intake, growth rate or mortality when they were under noise stress of military jet aircraft and panic occurred among them in pen. However, the results of RHEIN were different from those of COTTEREAU (1972), who subjected broilers at one day age to noise stress. He found that panic was not observed, nor was there any negative influence on their growth. The results showed that the effect of noise on growth rate and body weight of broilers varied depending on the breed and noise resistance. ROGOZHINA (1970) reported that the sudden death syndrome affected broiler breeding flocks at the onset of egg production. From an economic standpoint, this can affect the income of the farm and may thus be economically important for poultry men. There is clearly a need for further investigation in this field.

1.2.1.4. Influence of noise on other domestic animals

In some studies, the effects of noise on domestic animals other than hens have been investigated.

Different noise sources such as generator or diesel engines led to a decline with regard to weight gain capacity and food digestion in most sheep (AREHART and AMES, 1972). Noise pressure levels of 112 - 121 dB caused increased mortality of pigs (IVOS, et al., 1976). WINCHESTER et al. (1959) found that pigs in an experiment did not react to jet aircraft noise or adapted quickly.

CASADY and LEHMAN (1966) found that supersonic claps caused only slight reaction in horses, but low-level flights led to reactions such as escaping. Decreasing milk production due to bursting paper bags was mentioned by ELY and PETERSEN (1941). Unexpected noise of 105 dB could, however, decrease the quantity of milk at the next milking (KOVALCIK and SOTTNIK, 1971). Noises from motor boat races are reported to have decreased the milk production in cows nearby (ODA, 1960), and supersonic claps resulting in mild reactions of cows (EWBANK and MANSBRIDAGE, 1977) have also been reported. In a field study, ESPMARK et al. (1974) observed cows and lambs exposed to sonic bangs for four days. Behavioural reactions were considered minimal in both species. It was not mentioned, however, whether the animals had been exposed to similar noise before the beginning of the experiment.

1.2.1.5. Effect of music on domestic animals

The effect of music on animals, however, has not been well studied. Music in poultry houses may have a similar effect and would certainly help mask any sudden noises that could cause the hens to panic. Specially chosen music has a favorable effect on the productivity of laying hens (MICHAEL, 1983). CHRISTENSEN and KNIGHT (1974) found that various types of music had an effect on the growth rate of broiler chickens. GVARYAHU et al. (1989) found that evaluation of feeding behaviour indicated that chickens consumed significantly more feed than the control group particularly when the music was activated. In contrast, CHRISTENSEN and KNIGHT (1974) exposed meat type chicks to different kinds of music but failed to find any significant result. It is possible that the music factor may produce significant effects for the application of commercial production practices. The relevant literature contains information including the fact that music has a favorable influence on the behaviour of hens. JACKSON (1970) found that soft music (70 dB) at 0.5 - 2 kHz had a positive influence on the hens' performance.

Other reported research indicates that sound control can be used with beneficial effects. It is generally recognized that different vocalization of birds transmits meaningful information to other birds (FRINGS and JUMBER, 1954). The clucks of a broady hen will attract the chicks to feed; a tape recording of appropriate sounds could greatly facilitate acclimatizing newly hatched chicks to eat from a food hopper (MICHAEL, 1983). JACKSON (1978) describes recording happy singing sounds of hens on nest and playing them back to hysteria-prone flocks, thereby managing to reduce the incidence of flock hysteria. Swine may also respond in a favourable manner (BREEDEN, 1972).

Many farmers have used a radio to give their sows some varied stimulation, from rock music to classical music. Subjective impressions were that music made the animal quieter and less easier disturbed or distracted by sudden noises, an important consideration especially when piglets are nursing. Popular publications have contained reports that music is often played in the milking parlor and is said to make the cows milk more easily, possibly by stimulating the milk-letdown reflex (MICHAEL, 1983). Finally, if lack of stimulation is a problem in intensive environment, introduced sound, such as music, may have a role in future to help provide a more optimal level of stimulation for animals (PRESTON, 1983).

1.3. WELFARE

1.3.1. Definition

Welfare is a difficult concept both to define and to measure because it is not a single phenomenon but a combination of many factors. Such matters as nutrition, diseases, environmental factors and climate, as well as mental suffering of animals must be considered. Any judgement of husbandry environment for adequacy in regard to animal welfare must relate to all these factors (KILGOUR, 1978; PRESTON, 1983).

Concern about animal welfare has been promoted by books such as "The Question of Animal Awareness" (GRIFFIN, 1976); "Animal Behaviour " (TOATES, 1980) and "Animal Suffering" (DAWKINS, 1980). Likewise, "The International Journal for the Study of Animal Problems" was founded because of recognition of the need for scientific contribution to the welfare debate. In these publications a large amount of criticism has been directed towards agricultural animal practices, particularly in the intensive industries. Most intensive animal industries have had conference sessions or symposia on welfare. Governments too have typically responded by redrafting animal protection acts and their codes of recommendations for the management of livestock.

The attention of the general public was first drawn to the welfare of animals kept under intensive husbandry conditions by the publication of Ruth HARRISON's book "Animal Machines" (HARRISON, 1964). A useful definition of "welfare" is that of HUGHES (1976) : on a general level, it is a state of complete mental and physical health where the animal is in harmony with its environment. On an empirical level, it may be measured by studying an animal in an environment which is assumed to be ideal and then comparing it with an animal in the environment under investigation. Possible criteria for investigating welfare are biochemical, physiological, pathological, productivity and behavioural criteria.

In Britain, the public outcry was so intense that the Government formed a committee under the chairmanship of Professor Roger BRAMBELL to investigate intensive husbandry systems. In its report (Committee Paper 2836, 1965) the BRAMBELL Committee stated that "welfare is a wide term that embraces both the physical and mental well-being of the animal. Any attempt to evaluate welfare, therefore must take into account the scientific evidence available concerning the feelings of animals that can be derived from their structure and functions and also from their behaviour". Animal welfare is therefore something that should be kept in mind when environments for livestock are being designed.

Animal welfare in Belgium summarized very briefly states "Animals suffering overt cruelty or not receiving necessary care can be seized (General Protection provided by the Protection of Animal Act 2 July 1975). The member states of the Council of Europe Signatory hereto on 10 March 1976, dicussed the protection of animals kept for farming purposes, particularly in modern intensive stock-farming systems. It establishes a certain number of principles considering the housing, freedom of movement, provision with food and water, and care of the animals in accordance with their physiological and ethological needs. There are thus difficulties in defining welfare. In general, it appears that the concept of welfare is still useful.

Many animals, particularly mammals and birds, seem to have all the basic nervous apparatus for feeling pain and experiencing emotion. Common sense suggests that they can suffer. If animals do suffer from some of our scientific experiments, or from the way in which we keep them, from commercial profit, then it seems important on moral grounds to take this into account (DAWKINS, 1977). The term "suffering" implies a particular type of mental experience, a subjective consciousness; and that is what the BRAMBELL Committee (1965) was trying to take into account when they referred to "mental well-being" and "feeling of animals". Subjective feelings are not directly accessible to scientific investigation, but that does not mean that they do not exist (DUNCAN, 1981).

In his book "The Question of Animal Awareness", GRIFFIN (1976) has argued that there is compelling evidence from animal orientation and navigation studies as well as from animal communication studies suggesting that animals do have mental images, subjective feelings, and intentions. BUYTENDIJK (1958) has made a more comprehensive study of subjective feelings in animals and man. He showed that when deprived of visual cues, some animals, such as octopi (octopus), were able to distinguish between touching something actively and being touched passively. BUYTENDIJK interpreted this finding as demonstrating that animals above a certain phylogenetic level have a mental image of their immediate environment. The same was found with chimpanzees (MENZEL and HALPERIN, 1975). This adds up to something much closer to human mental experience. We should probably assume that the hen, lying somewhere between the chimpanzee and the octopus on the phylogenetic scale, has some intermediate capability for experiencing subjective phenomena (DUNCAN, 1981).

The behavioural scientist can provide objective evidence on such things as fear, frustration, conflict, pain and discomfort, as stated previously.

A question that remains to be answered is how the farmer treats the animals or understands their behaviour occuring throughout the working day routine. TEUTSCH (1978) has provided analysis of the ethical aspects of farm animal management. He stated that in principle man may be entitled to make an economic use of animals. However, when he makes such use, he must provide for conditions of life which are in accordance with the animal's natural needs and which guarantee its physical and psysiological health.

GROSS (1979) made the following important observations on improving farm animal welfare through education: "It is my experience that people who understand animals seldom subject them to inhuman treatment. My suggestion is that the best method for improving the welfare of experimental, commercial or pet animals is increased understanding of their behaviour and needs. Students who, after graduation, may work with animals should take a series of courses on animals' behaviour. Particular emphasis should be made on animals the student is likely to work with (e.g. student of animal husbandry, biology, psychology and veterinary medecine). Programmes of education through the extension service, human societies and other sources could help to inform those already working with animals of our current knowledge of their behavioural needs."

There has been a tendency to place too much emphasis on the physical and nutritional needs of animals with too little regard to their social and behavioural needs. It is easy to show our human bias while evaluating the animal's environment.

Evaluation should be made on the basis of careful observations by well-trained individuals. One of the most important variables in the animal's environment is the attitude of its human associates.

It can be seen from the review above that there are large gaps in the evidence required for the animal welfare. In coming to this conclusion, one possibility would be to follow some very general code that would be acceptable to the majority of the population (FOX, 1983). For example, the BRAMBELL Committee thought that an animal should at least have sufficient freedom of movement to be able, without difficulty, to turn round, groom itself, get up, lie down and stretch its limbs. In addition, a slightly more detailed set of guidelines to help farmers to ensure the welfare of their domestic animals under all systems of management was given by CARPENTER (1980). He claims that animals should have freedom to perform natural physical movements; association with other animals, where appropriate, of their own kind; facilities for comfort-activities (e.g. rest, sleep and body-care), provision of food and water to maintain full health; ability to perform daily routines of natural activities; opportunity for the activities of exploration and play, especially for young animals; satisfaction of minimal spatial and territorial requirements including a visual field and "personal" space. Once again these guide-lines would be acceptable for most people.

1.3.2. Determinations of welfare

Welfare of animals is a subject that can be raised whenever men come into contact with one of the other animal species which have evolved on this planet.

The more man interferes with the animal environment, the more difficult it becomes to decide which changes would be beneficial and which harmful to an animal. Is the welfare of a domestic chicken greater in an open run with a coop to provide only minimal protection from the weather, or in a battery cage inside an environmentally controlled chicken house with a constant supply of food and water, with a lack of freedom to move around. BELHARZ and ZEEB (1981) pointed out that a more natural or appropriate environmental design is needed to house those animals that spend sometimes part of the year outdoors, such as dairy cattle. In making the best reasonable estimate of welfare, it is essential to take account of all the evidence available (McFARLAND). Welfare indicators will be useful tools in allowing us to improve the living conditions of the animals that man is keeping for his own benefit.

Several indicators such as the following should be evaluated to determine animal welfare:

1) production,

2) physiology and biochemistry,

3) preference test and operant conditions,

4) behaviour, and

5) health.

1.3.2.1. Production

It is the general consensus among animal scientists, veterinarians, and others involved in the livestock industry that because animal welfare and productivity are closely correlated, industry's concern over maximizing productivity will guarantee a high standard of farm animal welfare (CRAIG, 1981). It has been claimed that suffering will result in a corresponding fall in productivity. Unfortunately, some stress effects may not be reflected in production losses (LOEW, 1972 ; BRYANT, 1972). The BRAMBELL Committee (BRAMBELL, 1965) states that temporary periods of acute stress will not necessarily decrease production. However, McBRIDE (1970) argued strongly that production is a good measure of assessing animal welfare.

EKESBO (1981) reported the widespread belief that the effect of animal environment on animal health or welfare can be inferred simply from the animals' production. This method is both deceptive and incorrect (FOX, 1983; EWBANK, 1973). The literature, however, suggests that production results are due mainly to the genetic capacity of the animal and the composition and quality of the food (BAXTER and FORSHAM, 1972). TAUSON (1979) confirmed that productivity was not a reliable indicator of the bird's overall welfare, since injuries to the birds' feet and throat had no negative effect on production.

The relative depth to width ratio of laying cages significantly influences battery hens' productivity and welfare. BELL (1972) described a new approach to cage design, and compared the conventional cage with a "reverse" or shallow cage, whose width was greater than its depth. His object was to increase the length of feeding trough per bird, and thereby perhaps to reduce any adverse effects of agonistic behaviour or social dominance during feeding.

The authors maintained that the increased trough length in shallow cages (which provide more trough space) could lead to economic loss from over-consumption in cooler climates, and savings in warmer climates where maintaining adequate nutrient intake can be a problem. ROBINSON (1979) has pointed out that the provision of additional feeding space, by whatever means, is extremely costly. It is much more difficult to make a statement regarding the effects on welfare. However, the reduction in mortality must unquestionably reflect again in welfare (DUN, 1982). Body weight increased in shallow cages and food intake increased as well (CUNNINGHAM, 1982 a), but there may be indirectly harmful effects in the greater weight predisposing to increased foot damage where the birds were housed on wire floor. The production parameters indicate that, where stocking density is the same in both types, welfare is no worse in the shallow cages (HUGHES, 1983).

TAUSON (1978) found that poorly designed feed troughs can lead to severe throat blisters from rubbing, and wire floors that were too steep can lead to a high incidence of foot sores, particularly on the matrix of the middle toe. Solid divisions between cages (instead of the usual wire netting) resulted in a 10 % improvement in plumage because of reduced wear and consequently some savings on food consumption because of reduced heat loss (TAUSON, 1983). Crowding of battery cages is a major factor in reduced profits for the egg industry and the influence on the welfare is considered. According to CUNNINGHAM and OSTRANDER (1981), hens housed under crowded conditions were more likely to lay cracked or ridged eggs.

DAWKINS (1980) also questions the validity of using productivity as an index of welfare. She explained that profits in agriculture were not made by setting up conditions in which each individual animal was maximally productive, or even maximally healthy. Rather, profits are made by running a whole farm unit efficiently which depends not just upon the animals, but also on the initial investment in housing and the considerable feed and labour costs once it is running. Economizing of space, for example, putting more hens into a battery cage, may lower individual productivity, but enable a large number of animals to be kept in the same area. This may more than compensate for the losses of each individual.

Eventually, RINGE (1971), in a detailed review of confinement rearing of poultry, noted that unfortunately economics often dictates the severity of the stress imposed by dust, noise, ammonia etc. that commercial operators are willing to tolerate.

1.3.2.2. Physiology and biochemistry

Another approach to the study of welfare is to monitor physiological parameters associated with reactions to a stressor. Physiological manifestation of stress in poultry was reviewed by FREEMAN (1971), SIEGEL (1980) and HILL (1983).

Welfare criteria as measured by physiological indices will vary from species to species and probably with breed, age and sex. Generalization should therefore be avoided, because what may seem right for one species may be wrong for another (ARAVE et al., 1973, 1974). SIEGEL (1971, 1980) reviewed the different aspects of physiological stress in birds. Adrenal gland weight, cholesterol and ascorbic acid depletion and plasma corticosterone have been used as tools to measure physiological stress for welfare criteria (CHRISTIAN et al. 1965; BRYANT, 1972).

The influence of population density on caged layer performance is of great interest to animal welfare activists. There was a positive relationship between number of birds per cage and corticosterone concentration (MASHALY, et al., 1984). They found that higher plasma corticosteroids were associated with higher density 48 hours after hens were placed in cages. The increase in circulating corticosterone observed in MASHALY's results was indicative of an active adrenal gland. Increase in adrenal weight as population density increased was reported previously in white Leghorn pullets and cockerels (SIEGEL, 1959, 1960).

An interesting interrelation between density and management has been observed in laying hens; in pen densities of 6 or 12 hens per square meter, and 2, 6 or 12 hens in (96 x 45) cm in colony cages. The other type of cage was a single-hen cage (40 x 38 cm) in which 1, 2 and 3 hens were housed. It was noted that increased hen density in pens resulted in higher level of plasma corticosteroids, cholesterol, decreased content of adrenal cholesterol and thyroid glands. No significant difference was found in plasma corticosteroids between different population densities in either of the two types of cages (ESKELAND, 1978). However, the levels of plasma corticosteroids, cholesterol, and urea nitrogen were lowest, and adrenal cholesterol levels and weight of adrenal thyroid glands were highest in hens in the small cages.

On the other hand, plasma cholesterol concentration was significantly higher in hens in colony cages and intermediate in those in a pen system (GROSS, 1980). KOELKEBECK and CAIN (1984) have reported that the lowest mean plasma corticosterone values occurred among hens in cages (0,79 ng/ml) and the highest on litter (1,72 ng/ml) with a range system intermediate (0,95 ng/ml). Plasma corticosterone concentrations have also been reported to be lower in caged hens than in floor hens (BARNETT and BARTLETT, 1981 ; CRAIG and CRAIG, 1985). Neither one of them found any marked difference in plasma corticosterone concentration between hens in cages or pens. Furthermore, other studies have shown that a decrease in floor space can chronically elevate corticosterone secretion (LEI et al., 1972).

Plasma corticosterone analysis late in the production cycle may not represent a particularly useful means of identifying chronic physiological distress for chickens in different environments (CUNNINGHAM, 1986). The latter investigator found that the lack of differences in plasma corticosterone levels for birds density, however, had been the result of adaptation of this response system over an extended period of stimulation.

CRAIG et al. (1986) have presented evidence that the plasma corticosteroid level declines over time for chickens housed in cages, and that corticosterone concentrations were not consistent with other indicators of hens' well-being thus indicating a need to look beyond corticosteroid assays for determining well-being. Time of sampling was found to affect the levels of corticosterone. CUNNINGHAM et al. (1988) noted that morning levels of corticosterone were significantly higher than the evening sampling.

Such conflicting results suggest that the corticosterone response to housing may be dependent not only upon stocking density alone but on a complex interaction with a number of other factors like breeds, sex, age and other environmental variables (ARANE et al., 1973).

On the other hand, the findings of GIBSON (1986) were that the concentration of plasma corticosterone is unlikely to prove a useful measure of long-term stress or an objective means of assessing welfare in different systems. He also mentioned that monitoring the thyroid hormone concentrations may not be a particularly suitable technique for assessing chronic stress in hens. However, DANTZER and MORMEDE (1983) concluded that, under closely controlled conditions, circulating corticosterone can be a measure of the animal's perception of its environment. In practice, however, the situation is apparently not so straightforward (BROOM, 1988). The only safe method seems to be the use of both corticosterone and thyroid hormones as simple and practical estimates of welfare. It is generally accepted that deprivation of food and water causes an increase in general activity of animals (BAUMEISTER et al., 1964), changes in adrenal cholesterol and total adrenal steroids during feed withdrawal (BRAK et al., 1979 b). BEN NATHAN et al. (1977) demonstrated symptoms of physiological stress during food and water deprivation.

According to the UK recommendation (1971), food and water should not be withheld for more than 24 hours. Similar limits are prescribed in the Swedish regulation (1974). The European convention for the protection of animals kept for farming purpose (1976) states that animals shall be housed and provided with food, water and care appropriate to their physiological and ethological needs.

When animals are handled, transported, exposed briefly to a predator or subjected to some operation, they show a range of behavioural and physiological changes which have the general effect of helping them to survive the treatment (BROOM, 1988).

There have been many studies which include the measurements of levels of adrenal products in the blood as an indicator of the responses of animals to short-term difficulty. An example of a research project, in which this measure was combined with other physiological measures, involved the assessment of the effects of different handling procedures and transport on hens which were being removed from battery cages and taken to slaughter (BROOM et al., 1986). In this study he found that rough handling had much greater effects than did gentle handling for a short period of transport.

The correlation coefficients between handling time and plasma corticosteroid concentrations were small and non-significant at 30, 49 and 50 weeks of age for pullets in floor pens and colony cages when times varied from 43 to 161 seconds. Yet, times of 180 to 600 seconds were associated with highly significant differences in corticosteroid level (CRAIG and CRAIG, 1985). However, ETCHES (1976) did not find any effect of handling on corticosterone levels with Leghorn hens when blood was obtained by venipuncture within one minute of removal from their cages. BROOM et al. (1986) found that transport does not lead to much greater effects than being kept in a stationary crate.

The most traumatic event in the lives of broilers is when they have to be caught for transportation to slaughter. Many get injured in the process, because each one has to be caught by hand and their carcasses will be downgraded which results in a significant loss for the producer (ASHBY and WEBB, 1974). GOODWIN (1978) studied the factors responsible for downgrading of broilers at a large processing plant. He found that catching crews were responsible for an estimated 40 % of the injuries. Another 25 % were associated with loading and unloading of the coops and post-slaughter struggling. DUNCAN (1986) was able to use heart rate changes in assessing the responses of broiler chickens to an automatic broiler harvester. This method was found to cause much briefer tachycardia than the catching of the hens by people.

Distances and waiting times create stress. It has been stated that 6.000 hens will loose 45 kg of weight per hour from such stress (FOX, 1983). Clearly there is great need for improvement in the transportation and handling of poultry and far more research is necessary to determine exactly which improvements are needed. Ultimately, it seems hardly possible to use such indicators for physiological stress in the field evaluation on a large scale. Also, many of the measurements, such as withdrawal of blood, or restraint, are themselves likely to be stressful (DUNCAN, 1981). However, the development of radiotelemetry techniques allowed certain physiological measurements to be taken with a minimum of interference to the bird (BEUVING and VONDER, 1977).

1.3.2.3. Preference tests and operant condition

A completely different approach to the assessment of welfare was first suggested by HUME (1956).

DAWKINS (1972) carried out extensive and fundamental preference studies in poultry. She mentioned that the major problem in an assessment of farm management systems that takes account of the welfare of the animals is how to consult the animals themselves. However, a method of assessing animal welfare which is specifically aimed at acquiring this type of animal-centred information, is to use preference tests as a way of telling how an animal views the world. A next step is to use operant conditioning techniques and see whether the animal will learn to press a lever or peck a key for the reward of being allowed either to obtain something or to get away from it (McFARLAND, 1981).

Such techniques, originally developed by psychologists for studying how animals learn, have now been applied in over 150 studies on farm animals to understand how they view various aspects of their environment; SCHMIDT and RAUTENBERG (1975) carried out experiments on pigeons whereas RICHARD (1976) and SHAWKAT (1985) used hens. For example, if we want to know whether hens dislike battery cages, the hens could be given the opportunity to choose between battery cages and some other environment. If it turned out that hens have a very strong preference for environments other than battery cages and if they would repeatedly perform some task for the "reward" of being allowed out of a battery cage, then we could say that they disliked cages. If, on the other hand, they did not seem to show a very strong preference one way or the other, we might be less inclined to say that they disliked them (McFARLAND, 1986; FOX, 1983).

The choice of situations may sometimes be biased, however, by the animal's prior experience, habitation to familiar situations, and fear of the unfamiliar (DUNCAN, 1978). The latter researcher found that battery-caged hens moved more quickly into a battery cage than they run into open air, whereas these used to living outside avoided the cages. For these hens it seemed likely that the battery cage was so abhorrent that they would suffer if confined there. In the case of hens used to living in cages, however, the preference for the run seemed much weaker and sometimes they actually preferred the cage. The argument that "cage-raised birds don't know anything else" (DAWKINS, 1983), and are, therefore, content to be in battery cages is an oversimplification. Adaptation (and possibly imprinting) to a given confinement system is to be expected if the animals were raised without any other choice.

From a human view-point it is sometimes difficult to know which conditions the animals themselves find unpleasant and which conditions are quite acceptable to them. The problem of bird welfare is approached from an animal-centred rather than a human-centred point of view (DAWKINS, 1976). In the case of poultry, where this approach has been used most systematically, the birds' own preferences may produce surprises (DAWKINS, 1977). Thus the BRAMBELL Committee (1965) recommended that battery hens would be more comfortable on thick rectangular metal mesh floors rather than on a thin hexagonal "chicken wire" mesh floor. The former flooring would have been very costly and would have increased the incidence of cracked eggs while being also uncomfortable for the hen's feet. However, when allowed to choose between different floor types, the hens actually preferred the cheaper chicken wire flooring.

Like other methods, preference testing has its limitations. For example, DUNCAN (1977, 1978) validly criticizes the choice approach by pointing out that there was no evidence that birds were capable of making decisions motivated by long-term interests. In addition, the birds do not always choose what is best for their health. This can be dealt with by ensuring that other factors are taken into account. DAWKINS (1977) also prudently adds that the effects of selective breeding and captivity could limit the usefulness of preference tests because birds might not always choose what is in their best interests. There is also the problem that choice tests focus attention on a single, simple environment instead of a complex environment with many choices in it (HUGHES and BLACK, 1973). Another objection is that "preference doesn't mean suffering" just because the birds prefer one thing to another or choose one set of conditions over another. This cannot be taken to mean that a bird necessarily suffers if it has to choose a least preferred state (SAINSBURY, 1986).

One interesting conclusion was drawn by DAWKINS (1980). She put forward that choice test and learning experiments could be a very valuable way of finding out how birds view their environment. It may in future be used to establish objective standards of welfare based on what the animals are known to find attractive or aversive.

1.3.2.4. Behaviour

One possible way of using behaviour as an indicator of welfare is to look for unusual or inappropriate behavioural changes. For example, HUGHES (1976 a) has pointed out that welfare could be measured by studying behaviour in an environment assumed to be ideal and then comparing it with that in the environment under investigation. However, one of the problems associated with measuring changes in behaviour of a domestic species is trying to decide what is "normal" or "natural".

Domestication has exerted its influence on the behaviour of species in two major ways. First, the species responds to the type of artificial domestic environment in which it is placed. Secondly, genetic selection of specific strains for certain desirable characteristics leads to even greater deviations from "normal behaviour" (BEILHARZ and ZEEB, 1981). However, we can get some idea of the relative importance of these effects by looking at the behaviour of domestic species in a wild or "natural" habitat. This has been carried out in detail with hens (DUNCAN et al., 1978).

The welfare of the bird is indeed sometimes difficult to judge and if its behaviour is taken as a measure of its welfare, a number of difficulties arise. Concerning an important activity of the chicken, for example feeding behaviour, several researchers have found contradictory results.

Some workers have reported a uniformly distributed feed intake during the entire day length period, others found one peak, two peaks or even three peaks (HUGHES, 1972; ANON, 1981). Certain birds which do not have the possibility to feed during the busy-hours due to a shortage of feeder length, will keep themselves busy in a rather bizarre way by preening and moving around in a highly nervous state (DUNCAN and WOOD-GUSH, 1972).

There have been many studies involving a comparison of the behaviour of poultry kept on at least two systems, one more intensive or artificial than the other (BAREHAM, 1976; HUGHES, 1978). BAREHAM (1972) observed that hens in battery cages "head-flicked" more than those on deep litter. According to VESTERGAARD (1978), the wire floor of the battery cage reduced the incidence of actual fights but correlated with an increase in aggressive pecking. It is known that hens prefer large to small cages (HUGHES, 1975). The increased cage pecking observed in the smaller cages may be a sign of frustration (ESKELAND, 1977).

Behaviour problems of farm animals have been studied by different researchers. Table 1.1 shows a list of the major behavioural or husbandry problems on poultry farms and their possible causes (FOX, 1983).

Stereotyped behaviour in animals, in certain contexts, may be a useful ethological indicator of frustration or anxiety. A chicken, unable to reach food when it is hungry, or to find a nest box when it is about to lay, will show stereotyped movements. The animal is apparently frustrated, and ethologists generally agree that such behaviour is a sign of stress and discomfort in birds (MOSS, 1980). Stereotyped movements are indicators of stress (MEYER-HOLZAPFEL, 1968), the severity of which is proportional to the intensity (frequency of duration) of the movements and their perseverance (or occasional intensification) when the environment is changed. Thus, a wild animal in a pen or cage and showing stereotyped behaviour when alone, often shows an increase in anxiety (or stereotype intensity) when a person enters its enclosure (HUTT and HUTT, 1965).

Table 1.1. Poultry behaviour problems (after FOX, 1983)

Behaviour or husbandry problems	Possible causes	References
Disease	Social stress	GROSS (1976)
Hysteria	Monotonous environment	FERGUSON (1968)
Ticks, head-flicking, and hyperactivity	Confinement	LEVY (1944)
Cannibalism	Nutritional deficiency (arginine), overcrowding stress	EWBANK (1969 a), ALLEN and PERRY (1975)
Feather pecking	Dietary imbalance and overcrowding, socially facilitated	EWBANK (1969 a), VESTERGAARD (1978), DUNCAN (1986 b)
Peck-out	Associated with prolapse of cloaca in battery layers, possibly "vice" or related to overcrowding	
Prelaying pacing	Lack of adequate stimuli for nesting	BAREHAM (1975)
Redirected aggression and stereotype behaviour	Crowding stress; feeding frustration	McBRIDE (1966), DUNCAN and WOOD-GUSH (1972 a)
Aggression and social stress	overcrowding; unstable grouping	McBRIDE (1968)

Pacing behaviour in poultry can become a highly stereotyped action, occurring when the bird is frustrated or is attempting to avoid some threat, or during the prelaying phase when it appears to be frustrated because it cannot find a suitable nest sit (WOOD-GUSH, 1972).

As with many stereotyped behaviours, the repetitive movements may be a compensatory action to increase sensory input and motor output (FOX, 1971 b). Although it might be argued that poultry are simple creatures whose essentially instinctive behaviour is governed largely by automatic releasers, WOOD-GUSH (1971) concluded that there is sufficient evidence to support the probability that, under reduced levels of stimulation and environmental complexity, poultry may suffer from boredom (DUNCAN and HUGHES, 1972). That means, boredom or reduced stimulation may be a factor in the development of abnormal behaviours in many animals (WEMELSFELDER, 1983). This could lead to feather pecking and cannibalism.

Feather pecking and cannibalism are extremely common problems in modern poultry husbandry (CRAIG, 1981). Feather pecking may develop as a displacement behaviour evoked by the frustration of boredom. Feather pecking can occur in relation to increased contact with other birds (crowding stress). Cannibalism may sometimes be traced to some dietary deficiency or to the form of the food, less cannibalism being reported in mash versus pellet or crumb-fed flocks. Genetics and environment (light intensity, ventilation, and type of housing) are also contributing factors. High temperatures and poor ventilation will also aggravate crowding stress and potential feather pecking and cannibalism (FERGUSON, 1968).

VESTERGAARD (1978) carried out a valuable study of this problem in battery layers. Their investigation evolved from an original study on the effect of group size and floor space allowance on battery egg production. The latter study was in progress when feather pecking and then cannibalism broke out among the chicks in some cages before 2 weeks of age. Attempts to prevent this by treating injured birds and by reducing light intensity failed.

It was concluded that feather pecking and cannibalism are separate phenomena, although the same cage conditions increased the incidence of both (HUGHES and DUNCAN, 1972). These authors proposed that cannibalism be divided into vent pecking and cannibalism affecting other parts of the body. They further pointed out how even a minor injury on a bird will attract many birds to peck at it if there is a blood on the birds' feathers. Blood (especially on a white bird) may be an important releaser for pecking, and may subsequently lead to extensive feather pecking and/or cannibalism.

It is particularly problematical when a behaviour pattern is missing under intensive conditions. For instance, wing-flapping does not occur in battery cages, and it has been said that battery cages prevent it (HUGHES, 1983; MARTIN, 1979). It is true that a commercial battery cage is not large enough to allow the full motor pattern to take place. However, there could be other explanations. Perhaps the battery cage does not stimulate or "release" wing-flapping or the bird in a cage is not motivated to flap its wings.

One question to be raised is why the bird does wing-flapping or how it develops or for what does the bird do wing-flapping. Wing-flapping is often described as the bird stretching its wings, but this is a purely subjective description. It could be a stretching comfort movement but it could also be a sexual signal or a social signal or an intention movement to fly. This pattern needs further investigation.

1.3.2.5. Health

Health is another criterion for the assessment of welfare of farm animals. Health includes not only the recognition of diseases caused by pathogenic micro-organisms but also any defect arising from injury or abnormality due to faults in nutrition, genetics, management or housing. Good health is the birthright of every animal that we rear, whether intensively or otherwise. If it becomes diseased we have failed in our duty to the animal and subjected it to a degree of suffering that cannot be readily estimated (SANSBURY, 1986). It is axiomatic that anything which reduces health will also reduce welfare.

The various ways in which health, and therefore welfare, can be affected by intensive systems has been described by LINDGREN (1978). He pointed out that it is often forgotten that the low incidence of avian tuberculosis and fowl typhoid observed today is partly due to the widespread use of cages that separate the bird from its droppings. On the other hand, all intensive systems increase the risk of spread of respiratory viral diseases. At the same debate, TAUSON (1978) and VESTERGAARD (1978) both agreed that the incidence of wear and tear injuries, ranging from feather damage to severe skin lesions, was very much greater in battery cages than on deep litter systems. TAUSON (1978) has pointed out that the range of cage equipment available on the commercial market varies enormously in the amount of injury it causes, and the fairly simple modifications can reduce injuries substantially. Although attention to animal welfare and humane treatment may enhance productivity, there is unfortunately no inevitable correlation between the two. FOLSCH et al. (1977) has indicated that poultry with extensive injuries may not be adversely affected according to a productivity criterion alone. He noted that of 26 severely injured battery hens, 50 % maintained normal egg production when placed in separate cages to protect them from further injury, even though the existing injuries received no treatment.

The claim is often made by agribusiness that "productivity is an infallible sign of health and general well-being". This is certainly not true (FOX, 1983).

Some poultry husbandry practices involve operating on the hen; for example, debeaking and declawing.

Debeaking is first done on the chicks soon after they are hatched. It must be repeated at a later age for laying hens, at which time the stress of capture and restraint is an additional negative factor. If done correctly, debeaking is believed to be a painless procedure (FOX, 1980). However, PEREK and BEDRAK (1962) investigated that chicks show a trend toward lower adrenal ascorbic acid 12 hours after being debeaked, a clear indicator that this procedure is stressful. Debeaking removes an important part of the bird's anatomy essential for preening, feeding, and self-defense. If improperly done, it will interfere with feeding efficiency and hence may reduce profit margin.

Declawing laying hens to reduce crowding stress, possible outbreaks of hysteria, and physical injuries that might adversely affect productivity, has been explored by some poultry scientists and producers. The ethics of this practice should be seriously considered. Such an extensive mutation at 23 weeks of age (or any age for that matter) could not be done without considerable pain to the birds and subsequent discomfort until the feet have healed (RUSZLER and QUISENBERRY, 1979). RUSZLER and KIKER (1975) found that claw removal at 1 day of age tended to decrease hysteria and increase hen-day egg production and livability in caged hens. CRAIG (1981) noted that declawing helped to reduce feather loss and related injuries in battery-caged laying hens, resulting in 7 - 8 % better livability, better feed conversion, improved back feathering, and 2 - 4 % higher rate of production. Declawed hens had more serious foot problems since claw removal reduces the effective area for support. However, other researchers conclude that birds declawed do not probably suffer, because egg production was not adversely affected and the birds had lower corticosterone levels than controls.

Anaesthetic drugs could be used more widely during animal operations, again, however, their use is not without problems. The administration may in itself be stressful because of the handling, restraint and injection procedures (PRESTON, 1983).

Health, the absence of physical evidence of disease, has become a limited indicator of animal welfare since treatment with drugs and other practices can have a "masking" effect. For example, antibiotics can prevent diseases from appearing, but they do not alleviate causal stressors, even though they reduce the suffering associated with actual disease.

One may harm an animal's physiological system without actually causing it pain or immediate suffering. For example, continuous lighting to stimulate poultry to eat constantly may do harm to their metabolism and be a physiological stress, but not cause the animals any pain or distress. Thus, an important aspect of animal welfare lies in the recognition and minimization of husbandry practices that may not necessarily cause apparent pain or demonstrable suffering, but that may actually harm the animal (FOX, 1983).

2. MATERIALS AND METHODS

2.1. EFFECT OF HIGHWAY AND FEEDING MACHINE NOISE STRESS ON LAYING HENS

2.1.1. Hens and management

Experiments were carried out on 400 hens (Gallus domesticus). They were fed on commercial layer rations. Water was provided through drip nipples and located at the side of the cages; each cage has its own nipple drinker. During the laying period, a 16 % protein layer ration was supplied to them. The hens were housed at 20 weeks of age and the experiments started at 22 weeks, allowing 14 days for adaptation. The lighting system provided 16 h light / 8 h darkness daily. Feeding and egg collection were done by hand. All hens were laying regularly. They were healthy and had no diseases during the research period.

The investigation was made on 3 groups, the first group with no noise was considered as a control (a), the second group was exposed to noise produced by the feeding machine (b) and the last group loaded with noise of a highway (c).

2.1.2. Hens house

The cages were located in the three experimental rooms with an environmentally controlled climate. Temperature was generally maintained between 20-22 °C and relative humidity did not exceed 60 %. The rooms were ventilated by a 30 cm exhaust fan providing a constant circulation of fresh air in each room. During colder periods, three electric heaters provided warm air in a forced flow. These heaters were switched on and off, according to the circumstances. The house was illuminated by means of a total of twelve 30 W fluorescent tubes, situated on the wall, close to the ceiling and located in pairs.

2.1.3. Noise loading

Noise pressure levels are expressed in decibels and measured with the DECIBEL precision sound meter type 2215. Sound levels in the control group were 55 dB.

2.1.3.1. Highway noise

The group was exposed to the noise of car engines mainly, recorded by a tape recorder at the edge of a highway. The hens were subjected to the following noise stress regime: 2 hours of noise stress, followed by 2 hours without noise stress. This regime was repeated alternatively during the day time only with a noise intensity of 90 - 95 dB. In the second phase of investigation the hens were subjected to various noise levels : 60, 65, 70, 75, 80, 85, 90 and 95 (dB), each for 30 minutes in random order. Each test was replicated 4 times per level. The noise source was located in the middle of the group.

2.1.3.2. Feeding machine noise

Experimental hens of the third group were exposed to the noise generated by a feeding machine on a commercial farm, as recorded by the tape recorder. The background noise levels on the farm - including the noise of the ventilation system - was 55 - 60 dB.

When the machines were in operation, the average noise level was situated between 75 and 80 dB. However, during feeding times noise levels could exceed 85 dB.

Hens were subjected to the feeding machine noise by playing the tape recorder 4 times a day for 30 minute periods each. The noise was synchronized with feeding time at 08.00, 10.00, 12.00 and 15.00 hours. The experimental hens have been subjected to different periods of feeding machine noise exposure which started by 10 up to 60 minutes. Each test was replicated 6 times.

2.1.4. Video equipment

The equipment consisted of two cameras (PHILIPS black/white type VK4902/20) in a protective housing (type 38 AV 5045/005) and connected to a video recorder (PHILIPS, model no. 6464/00S). The cameras were mounted on a tripod which allowed easy adjustment. Recordings were stored on high density tape (Maxell high grade, cassette) and were viewed on a monitor (PHILIPS type 12TX 3512/00W).

2.1.5. The data recording schedule

Recording began at 08.00 o'clock in the morning and continued until 18.00 o'clock.

Hens were watched from a distance of about one meter by video camera. Videotapes were changed after four hours of recording and this did not cause any disturbance to the hens as the recorder was placed in the control room outside the experimental house.

All measurements were collected for individual cages by the same observer using the same apparatus. All behavioural activities were processed as counts. The time spent for performing some of the activities was measured as well. The observations were made six times a day at 08.00, 10.00, 12.00, 14.00, 16.00 and 18.00 hours. The latter measurements were performed over a period of 60 minutes (preening) or per day for behaviour which was observed less often (wing/ legs stretching). For each group, 30 cages were observed on a total of 90.

2.1.6. Analyzed parameters

2.1.6.1. Production

All data were collected starting from 2 to 4 weeks after the time of housing to the end of the experiment.

Egg production in individual cages was recorded daily from 22 to 60 week of age. The number of eggs per hen was calculated for each cage by dividing the total number of eggs produced by the number of hens originally housed in the cage and registered as a percentage. Mortality was registered as it occurred by individual cage and all the dead hens were sent for analysis to the Faculty of Veterinary. Poultry Diseases Department of the State University of Gent. The body weights of 50 % of the hens were measured every 50 days and weight gains were recorded.

Feed consumption was determined biweekly and estimated by weighing the remaining food in the trough. Mean feed conversion per group was computed as total feed consumed over total egg mass during the experiment. The numbers of broken and dirty eggs were recorded daily. These data provide information on the influence of various noise levels between 60 and 95 dB on both egg production and the amount of dirty and broken eggs. The second part of the experiment started with 60 dB and then repeated at 5 dB intervals up to 95 dB. The noise levels themselves being chosen randomly.

2.1.6.2. Egg quality

Individual egg records were obtained throughout the study. Eggs from each group were collected twice daily at 11.30 and 15.30 h. All were gathered by hand, stored on trays while being individually marked, and carefully transferred to the laboratory where they were examined, identified, graded by an egg grader and sorted by weight into seven categories according to Belgian weight grade standards. The distinguished categories were:

1. + 70 g
2. 65 - 70 g
3. 60 - 65 g
4. 55 - 60 g
5. 50 - 55 g
6. 45 - 50 g
7. 45 g

Information on egg grades was obtained from a one day collection every 3 weeks.

Per group 70 eggs were selected at random after determining the weights. These eggs were broken and their contents removed. Shells were washed with tap water to remove any residual albumen. Shells were allowed to dry at room temperature for at least 24 hours. Taking the average of three measurements at the blunt end, the equator and the pointed end for individual eggs, shell thickness was determined and measured by a micrometer. Samples were measured on a monthly basis.

The weight percentage of shell was calculated by dividing shell weight by total egg weight. Incidences of meat or blood spots were noted and the effect of different noise levels on the frequencies of meat and blood spots was studied. Shell deformation was also recorded monthly.

2.1.6.3. Behaviour-related parameters

The parameters observed can conveniently be regarded as forming five broad categories. Behaviour-related parameters were recorded from 24 to 60 weeks of age. The obeservation were made on 30 hens.

A. COMFORT BEHAVIOUR

The ability of an environment to provide for the comfort of animals may be an important criterion for assessing it. Eight important species-specific behaviour patterns of laying hens were studied in the present investigation.

Head shaking

The head, held normally, is moved from side to side accompanied by a slight raising of the head and neck feathers. This movement occurs during feeding, drinking or nesting time.

Body shaking

The neck and body feathers are ruffled and the entire body is rotated in an axial plane. Wings are slightly lifted.

Wing flapping or attempted wing flapping

The flapping action involves a bilateral movement of the wings, including wing raising (figure 2.1).

Preening

The beak is brought into contact with the feathers and various movements are performed for cleaning the feathers (figure 2.2).

Wing and leg stretching

Unilateral backward and downward stretching of wing and leg together (figure 2.3).

Turning

Change in orientation of 180° about the long axis.

Sitting

Time spent sitting on the cage floor. To be classified as sitting, a hen has to adopt such a posture that the hocks are fully retracted against the body with the shanks parallel to the floor of the cage (figure 2.4).

Standing

When no other activity is recorded and hens are not sitting (see figure 2.5).

B. MAINTENANCE BEHAVIOUR

This category includes feeding and drinking behaviour. Observations were made on whether the hens' heads were down in the feeder pecking or making swallowing movements. Incidence of the following 4 parameters was recorded: (a) the number of feeding bouts; (b) total feeding time; (c) the amount of food eaten; (d) the number of hens eating together at the trough. The first three of these parameters were measured at individual level. Drinking behaviour was recorded when the beak was

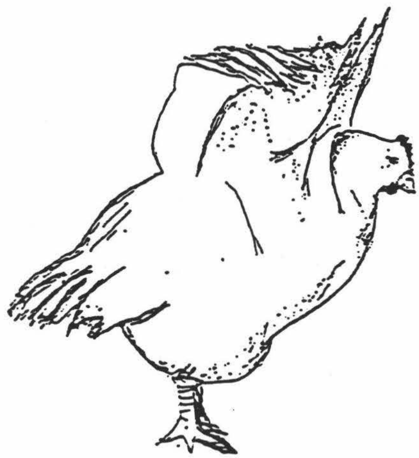


Figure 2.1 : Wing-flapping behaviour

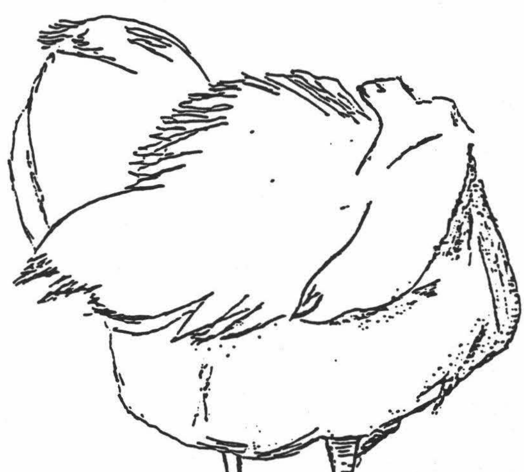


Figure 2.2 : Preening behaviour

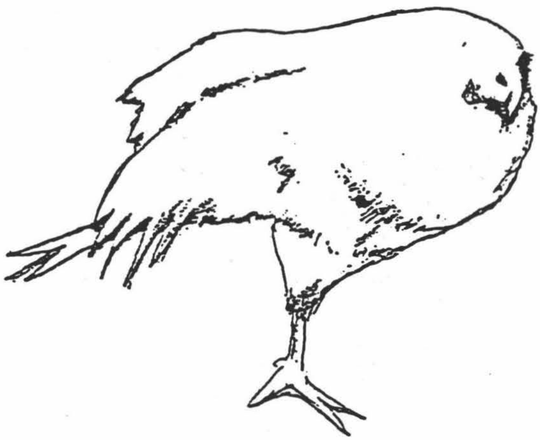


Figure 2.3 : Wing/leg stretching behaviour

Figure 2.4 : Sitting behaviour

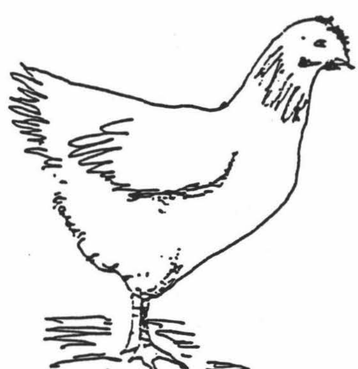


Figure 2.5 : Standing behaviour

pecked at the water nipples and so was the time spent drinking water. The number of pecks at the nipples was counted.

C. HENS POSITION

The location of hens in a cage was recorded. Hens were classified as being either in the front or in the rear of the cage. Positional behaviour of hens was measured as the time spent in the front or in the rear of the cage during a 60 minute period.

D. AGONISTIC BEHAVIOUR

Aggressive *pecks* were defined as those directed towards the head, generally causing the other hen to retreat. This activity was recorded over a 60 minutes period and observed between 24 and 60 weeks of age. Pecks directed towards other parts of the body of the closer or neighbouring hens (figure 2.6) and pecks at the cage (figure 2.7) or trough were also recorded. ***Pushing*** involves body contact initiated by a hen and resulting in a clear displacement of the partner. Locomotor pushings are made mainly with the shoulder or with the side.

E. ABNORMAL BEHAVIOUR

Noise, as an environmental quality factor, can cause changes in behaviour. In this category attention was paid to the occurrence of abnormal behaviour. Following activities were observed :

1. *Feather pecking*: pecking and pulling feathers of other birds, sometimes eating these feathers. As previously noted, feather pecking might also have been included in this category.

2. *Cannibalism*: pecking at vent area, tissue or toes of other birds. This pecking is followed by eating the tissue which is pecked and may cause death of the victimized hen.

3. *Jumping* more than once, generally disturbing the other hens and resulting in nervousness or frightening.

4. *Moving randomly*: upward and forward movement of the body and pushing off with body and wings or in agitation position.

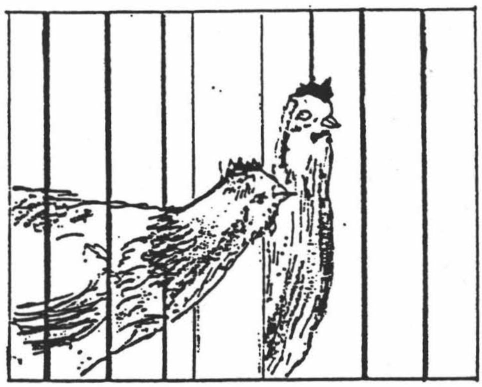


Figure 2.6 : Hen being feather-picked by neighbour

Figure 2.7 : Cage pecking behaviour

2.1.6.4. Economic parameters

The economic aspects were studied by recording egg production and feed consumption. Mortality and egg loss (broken, dirty or abnormal eggs) were registered daily and should be considered in determining hen-egg production. These factors affect eggs income to a considerable extent. Economic parameters were expressed on a per cage basis, after adjustments for mortality differences among the three groups. A cull price (salvage value) of 27 BF/kg was used to determine receipts from the sale of hens at the end of lay. The blended egg price of 2.57 BF/egg was used to determine receipts from the sale of eggs. A feed price of 10 BF/kg was used to calculate costs associated with hen feed intake. Costs associated with rearing hens and fixed costs per cage (one cycle of lay) were also accounted for.

Cage profits are given by the following equation:

cage profits = gross returns/cage - total costs/cage

2.1.7. Determination of calcium, magnesium and phosphate

2.1.7.1. Sample preparation

Up to 0.5 g of ground egg shell was placed in a 100 ml beaker, 10 ml HNO_3 was added and digestion on a hot plate was allowed for 30 minutes. The beaker was covered with a watch glass.
The suspensions were filtered and washed with distiled water into a 50 ml volumetric flask provided with a mark for distiled water.

2.1.7.2. Determination method

Calcium, magnesium and phosphate contents in the extracts were measured as follows:

1. Calcium was measured by flame photometer (Model: ELEX 6361)

2. Magnesium was determined with an atomic absorption spectrophotometric (Model: VARIAN AA 1415)

3. Phosphate was determined colorimetrically with a U.V.-visible spectrophotometer at a wave length of 430 nm.

2.1.8. Scoring methods for the plumage condition of laying hens

Two main methods were used for subjective scoring.

1. First method

The feather quality of the whole body was scored by giving a single figure, i.e. a number of points. 20 points is the maximum score given to a hen which has a very good feathering. This criterion has been used by several researchers, e.g. HILL and HUNT (1978, 1981), AMBROSEN, (1982) and TAUSON (1984).

2. Second method

Hens were scored for the feather condition of five individual parts of the body, i.e. neck, breast, back, wings and tail (TAUSON, 1983), according to the following scale:

Score	Description
4 points	a very well-feathered body part
3 points	a body part where feathers had deteriorated, but with the body still completely or almost completely covered
2 points	a body part where feathers had very clearly deteriorated and/or showing large naked areas
1 point	a body part with heavily damaged plumage, showing no or only very small areas covered with feathers

Separate scoring of individual body parts as compared to whole-body scoring should only be considered as providing more specific information on the probable causes of feather loss by a certain treatment. However, the advantage of scoring the entire body is that one single figure gives a more clear-cut view of the differences in plumage conditions of the hen.

Data were collected for feather condition from 8 weeks after housing onwards. A total of 180 hens were scored and compared each time. They were randomly selected in each group at 28,34, 44, 52 and 60 weeks of age. The plumage condition of the hens was scored from 90 cages (= 2 hens/cage) per group by the two procedures independently.

The final score for plumage condition was obtained by taking an average of the score derived from the simple whole-body scoring technique and that obtained from the five-part method.

2.1.9. Corticosterone in blood plasma

2.1.9.1. Blood sample

When more than one hen has to be caught and sampled for a short period, there is a particular concern about the effect of time required for the handling of hens and its possible effect on corticosteroid concentrations in the blood plasma. Therefore, only a single hen was caught from a particular cage on one day.

Extreme care was taken (a) to minimize the hen handling stress and (b) to randomize group samplings. Hens were ordinarily carried to a control room for blood sampling. After capturing the hens, all necessary equipment was ready in the control room and located less than 3 meters from the place from which the hen was taken.

For withdrawal of the blood samples from the vena saphena, there is no need to remove the feathers as it may harm and cause stress to the hen. By this means, samples were easily obtained with an average handling and blood taking time of 45 seconds.

About 2 ml of blood were withdrawn from 30 hens for each group and each sample was replicated 2 times per hen. Blood samples were collected at 3 p.m. to minimize the increase in the corticosterone levels.

All blood samples were centrifuged for 10 minutes, put into another labeled tube, and frozen at -20 °C until analyzed. Thirty hen replications were considered to be an experimental unit within each group.

2.1.9.2. Determination of corticosterone by radio-immuno assay

Blood withdrawal techniques have been described above. A radio-immuno assay (RIA) procedure was used to measure the corticosterone concentration in all serum samples.

Assay aliquots of 0.5 ml of plasma were extracted with anhydrous ether, dried with nitrogen and reconstituted with a buffer, and duplicate samples were assayed. Intra-assay and interassay variability for the RIA were 10.3 and 6.3 % respectively. Cross-reactivity with 14 other steroids was determined and desoxycorticosterone gave the highest cross-reaction (1.86 %). The assay is validated as described by WENTWORTH et al. (1976).

The experiments performed were designed:

1 - to study the effect of noise on the corticosterone concentration

2 - to find the relation between age of hens and hormone level in the plasma; blood sample collection was performed from 28 up to 64 weeks of age.

3 - to determine the effect of different exposure periods of feeding machine noise levels on the corticosterone concentration. Experiments were started at 00.00 h; the birds were exposed to consecutive periods with noise lasting from 10, 20, 30, 40, 50 up to 60 minutes. Each test was replicated six times.

4 - to investigate the influence of various noise levels on the corticosterone concentration. The experiments started with 60 dB and then repeated at 5 dB intervals up to 95 dB, the noise levels themselves being chosen randomly. Each noise level was repeated six to eight times.

5 - to determine whether or not there were differences in corticosterone level before and after subjecting the hens to feeding machine noise. Blood sampling was performed before and after the period of noise, at 14.00 h and 16.00 h respectively.

2.1.10. Categorization of abnormal eggs

Eggs were collected twice a day from the three groups. Data were assessed weekly. Then eggs were classified into 6 categories of surface defects. All eggs were examined individually and placed into one of the following six categories:

1. normal
2. brown deposits
3. misshapen
4. chalky deposit
5. dusty
6. other (soft shell, shell-less, bulge or white banded)

Data were registered weekly for abnormal eggs of the morning and afternoon periods to determine whether the noise level (60 - 95 dB) influenced the frequency distribution of normal and abnormal eggs.

In the second part of the experiment, eggs were collected from three groups in the morning and in the afternoon for 3 days. The objective of this part was to determine whether there are differences in the proportion of abnormal eggs between eggs collected in the morning and in the afternoon under noise stress.

2.2. LAYING HENS UNDER FEEDER LENGTH STRESS

2.2.1. Hens and management procedures

A total of 262 laying hens of a commercial grower were used in this study. The experiments started at 22 weeks of age, the hens weighing between 1.5 and 1.75 kg. They were kept up to 60 weeks of age. The project ran from May 1987 to August 1988, at the Faculty of Agricultural Sciences of the State University of Gent.

Drinking water and food were provided; all hens received the same ration from 20 weeks until the end of the investigations.

Fourteen hours of light were provided at 20 weeks of age, with an increase of 15 minutes per week until a 16 hour light period was reached. After that the lighting regime was maintained at 16 hours of light and 8 hours of darkness daily.
The experimental house was ventilated by 3 exhaust fans providing a constant circulation of fresh air. Relative humidity was not controlled, but remained constant throughout the experimental work and did not exceed 60 %. The temperature was maintained at about 21 °C. Temperature and relative humidity were registered by thermohygrographs. The hens were vaccinated when one day old for newcastle disease and infectious bronchitis during rearing.

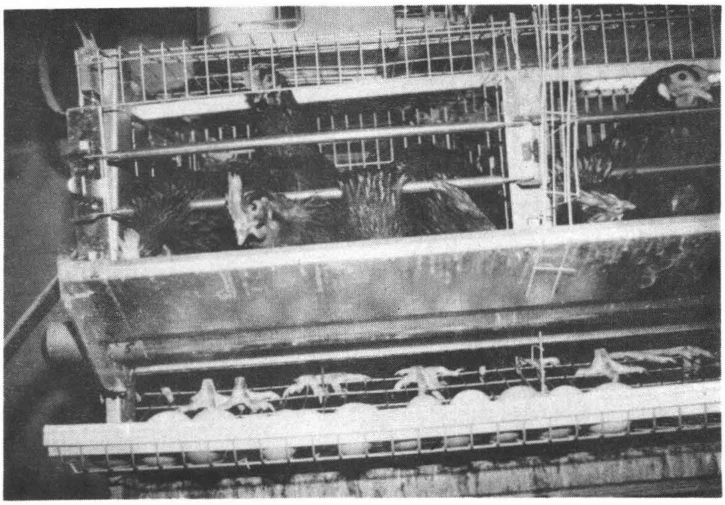
2.2.2. Cages

In the present study 60 cages were used. The cages were located in the experimental house. Hens were housed with densities of 3, 4 and 5/cage in a row of three-tier cage battery. Cages were assigned on the basis of feeder lenght per hen, reslulting in units with 10, 12, 12.5 and 13.3 cm/hen in the type I, II, III, IV-cages respectively (plates 2.1 and 2.2).

There were 15 replicates (cages per treatment combination for a total of 262 hens). The treatments are described more in detail in table 2.1.

Four different feeder lengths were used. The floor area per hen was 450 and 506 cm^2, respectively, with 5 hens in cage I and 5, 4 and 3 hens in cages II, III and IV. The cage designed such as to allow determination of the effect of feeder length on the laying hens. The cages were divided into four categories based on feeder length per hen, resulting in units with 10, 12, 12.5 and 13.3 cm/hen in I, II, III and IV cages (plates 2.1 and 2.2).

I



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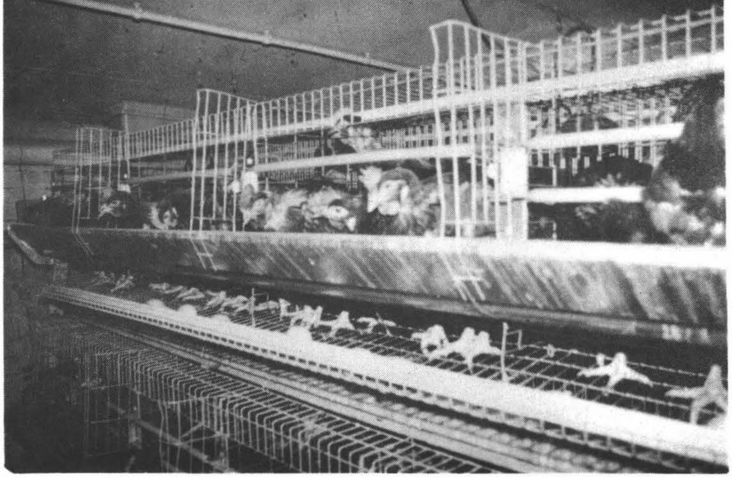
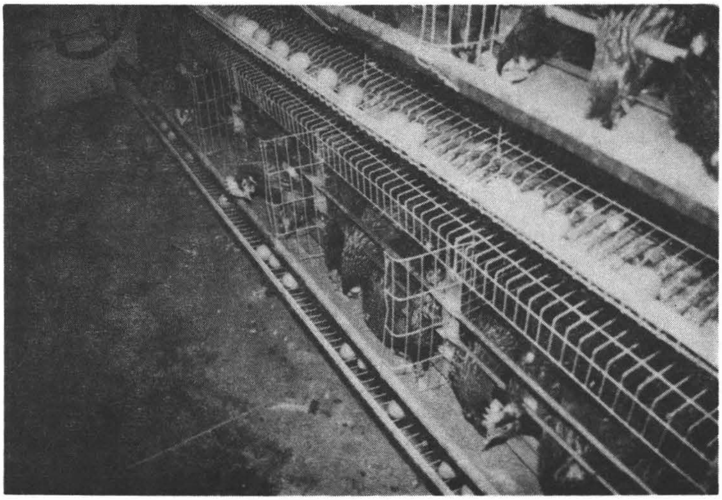


Plate 2.1.: Cages numbers I and II with 10 and 12 cm feeder length per hen (5 hens/cage)

III



IV

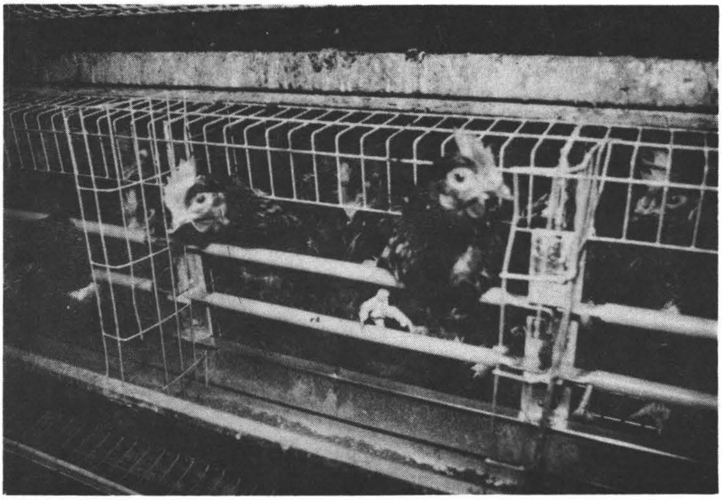


Plate 2.2.: Cages numbers III and IV with 12.5, 13.3 cm feeder length per hen (4 or 3 hens/cage, respectively)

2.2.3. Behaviour

Observations on the behaviour of hens were taken five times a day for 3 days a week at 08.00, 10.00, 12.00, 14.00 and 18.00 hours. A 60 minute observation was made on hens for the four cage systems. Data were recorded from 24 to 60 weeks of age. (procedure outlined in 2.1.6.3.).

Table 2.1 : Description of cage dimensions

Traetment	No. hens/ cage	Dimensions width x depth (cm)	Feeder length/ hen (cm)	Floor area/ hen (cm^2)
cage I	5	50 x 45	10	450
cage II	5	60 x 42.2	12	506
cage III	4	50 x 40.5	12.5	506
cage IV	3	40 x 38	13.3	506

2.2.4. Other records

It can be useful to relate behavioural information to other measures when comparing different cages. Relevant information was collected from 22 to 60 weeks of age.

2.2.4.1. Production data

Data taken, with frequency of collection in parenthesis, included: egg production (daily), mortality (daily), bird weight (50 days), feed consumption (2 weeks), dirty or broken eggs (daily). Data on egg weights and egg grades were obtained from one day's collection of eggs every 3 weeks. Weight gain and feed conversion were determined.

A total of 225 eggs were collected from the treatment groups for studying the effect of feeder length on laying performance. Egg quality was determined 5 times during the investigation, when the hens were 28, 36, 43, 50 and 60 weeks of age.

Eggs were weighed individually immediately after collection. Shell deformation was determined. The egg was then broken on a glass sheet and the presence of blood or meat spots in the egg was registered. The shell thickness was measured.

2.2.4.2. Feather scoring

For feather scoring hens were removed from their cages and inspected individually. The animals were chosen at random until a suitable sample size was obtained for the group being sampled. A team of three people - 2 assistants and the main scorer - did the handling and scoring of the hens. Two methods for feather scoring were used. The same methods as described in the previous part (2.1.8.) were used. The hens were scored at 28, 34, 44, 52 and 60 weeks of age.

2.2.4.3. Corticosterone level in blood plasma

The plasma corticosterone level has been used in this investigation as an indicator of physiological response to the feeders length stress.

Fifteen hens from each treatment were sampled every 6 weeks. The hens were caught on a random basis with as little disturbance as possible (procedure outlined in 2.1.9.).

2.2.4.4. Economic parameters

Total feed usage and net egg income over hen and feed costs were calculated at the end of the experiments.

Total hen costs and feed costs per hen were determined using an individual hen cost of 155 BF/hen and feed costs of 10 BF/kg. Egg income was determined by using egg values derived from price reports for the period studied.(May, 1987 to August, 1988).

Selling the hens at 27 BF/kg after the end of the experimental period adds extra income. The profits of the cage for each treatment were estimated by this formula:

Cage profits = gross returns/cage - total costs/cage

2.3. STATISTICAL ANALYSIS

The raw data were subjected to the analysis of variance treatment. The data were further evaluated by means of a paired t-test and DUNCAN's multiple range test. All results are presented as means ± standard error of the means.

3. RESULTS

3.1. Effect of noise on laying hens

3.1.1. Production performance

Before the exposure to noise, egg production was recorded to check both the equipment's operation and the hens' reaction to the environment.

In the group treated with highway noise, the production percentage was significantly lower than in the control group. A small difference was apparent in the group provided with feeding machine noise, although this failed to reach a significant level compared with that of the control group (table 3.1).

The regression formula representing the egg production versus the different noise levels of highway (60 - 95 dB) is:

$$\text{Egg production} = 113.65 - 0.55.\ \text{noise level (dB)}$$

$$r = -0.94$$

The negative correlation coefficient means that the higher the noise level, the lower the production of eggs. The data relating to egg production of the group exposed to various levels of highway noise are shown in table 3.2.

Hens in the control group laid significantly more eggs ($p < 0.01$) with at the same time a higher percentage of eggs grading (60 - 70 and + 70 g) when compared with the hens in the noise loaded groups: hens under stress (feeding machine and highway noise) produced a higher percentage of undergrade eggs. The data obtained are presented in table 3.1.

Feed intake per hen per day and feed conversion values were significantly ($p < 0.01$) affected by highway noise too. Hens in the control group [a] used less feed and had better feed conversion figures than hens in the group exposed to highway noise [c]. Although feed conversion differences were also observed between the control group and the group loaded with feeding machine noise [b], these were not significant. The difference between the feed intakes of hens in groups [a] and [b] was statistically significant.

Table 3.1 : Effect of feeding machine and highway noise on the production performance of hens. Results represented as means ± standard error (n = 120)

Parameters	Control (a)	Feeding machine noise (b)	Highway noise (c)	Level of significance ab	ac	bc
Egg production (%)	80.45 ± 1.8	79.4 ± 1.4	69.9 ± 2.4	N	**	**
Egg mass (g)	47.36 ± 1.6	44.72 ± 1.1	40 ± 1.04	N	**	**
Feed intake (g)	111.3 ± 0.8	114 ± 1.09	116.8 ± 0.9	*	**	*
Feed conversion	2.38 ± 0.09	2.55 ± 0.06	3.01 ± 0.12	N	**	*
Body weight (g)	2 112 ± 19.2	2 012 ± 85.19	1 991 ± 48	N	*	*
Dirty and broken eggs (%)	3.8 ± 0.51	8.28 ± 1.58	12 ± 1.9	**	***	**
Mortality (%)	5.2 ± 0.1	11.6 ± 0.3	18.4 ± 0.2	*	***	**
Eggs grading : 70 g (%)	37.8 ± 3.28	32.7 ± 2.34	24.4 ± 3.71	N	**	*
Eggs grading : 60 - 70 g (%)	44.3 ± 2.35	35.3 ± 3.16	26.9 ± 2.48	*	***	**
Undergrades (%)	4.9 ± 0.72	10.36 ± 1.3	18.46 ± 1.4	*	***	*

* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$
N : non significant

Final weights are given in table 3.1. The greatest body weights values were found in group [a] and they were significant compared with another group [c]. The body weights of hens in group [b] were intermediate between [a] and [c].

Table 3.2. Influence of differences in noise level of highway (dB) on egg production as well as on the proportion of dirty and broken eggs (n = 130). Results represented as means ± standard error

Noise level (dB)	Dirty and broken eggs (%)	Egg production (%)
60	5.0 ± 0.56	80 ± 1.48
65	5.8 ± 0.75	78 ± 1.66
70	10.3 ± 1.54	75 ± 1.19
75	11.9 ± 1.25	77 ± 1.16
80	14.1 ± 1.27	73 ± 1.89
85	15.5 ± 1.89	70 ± 2.31
90	17.0 ± 2.68	65 ± 3.02
95	19.7 ± 2.10	59 ± 2.55

There was a significant difference in frequency of dirty and broken eggs : in the control group [a] the percentage was (3.8 ± 0.5) whereas in groups [b] and [c] the frequencies amounted to (8.28 ± 1.58) and (12 ± 1.9) respectively.

The regression equation relating dirty and broken eggs to the noise level (60-95 dB) is:

$$\text{dirty and broken eggs} = -20.19 + 0.42 \;.\; \text{noise level (dB)}$$
$$r = 0.83$$

The simple correlation indicates that the occurrence of dirty and broken eggs was well associated with the level of noise and, considering the high coefficient of correlation, this relation was positively significant.

From the beginning to the end of the experiments 7 (5.2 %), 13 (11.6 %) and 30 (20.4 %) hens died in groups [a], [b] and [c] respectively. Mortality was higher between 45 and 64 weeks. Noise stress had a consistent effect on mortality; some of the deaths occurred in healthy hens. There were no obvious signs of disease and most of the deaths noted occurred in the group treated with feeding machine noise.

All results concerning the production performance are shown in table 3.1.

3.1.2. Egg quality

The noise level was significantly ($p < 0.01$) correlated with average egg weight. The results showed that eggs from hens in control group [a] were significantly heavier compared with eggs from hens treated with highway noise. However, differences between the weight of eggs produced by the control group on the one hand and by hens exposed to feeding machine noise on the other hand were not significant (table 3.3).

Shell quality was influenced by noise ($p < 0.01$). Shell thickness decreased and shell deformation increased in the group exposed to highway noise [c]. This means hens in the control group produced eggs with thicker shells than those in groups [b] and [c]. However, there was little change in the shell thickness of eggs produced by hens exposed to feeding machine noise and there was no significant difference between groups.

Eggs laid by hens in group [c] were significantly ($p < 0.01$) lighter (56.91 ± 1.8) and had significantly smaller shell weight (4.0 ± 0.26) and shell percentage (7.02 ± 0.41). Shell weight and percentage were greatest in the control group (6.51 ± 0.16, 9.84 ± 0.44). There were no significant differences between groups [a] and [b].

The frequencies of meat and blood spots were less in the control group [a] compared to both groups [b] and [c]. The registered data indicate that the noise of the feeding machine and the highway affected ($p < 0.001$) the incidences of meat and blood spots. The presence of meat and blood spots was most frequent in the eggs of hens treated with highway noise (22 ± 1.61), and it is significantly ($p < 0.01$) related to the level of highway noise (60 - 95 dB). Measurements of meat and blood spots were made at 8 various levels of noise. The data obtained are presented in table 3.3. The corresponding regression lines are shown in figure 3.1. The regression equation was found to be

$$\text{meat and blood spots} = -29.13 + 0.60 \cdot \text{noise level (dB)}$$
$$r = 0.96$$

Table 3.3 : Effect of exposing laying hens to feeding machine and highway noise on egg quality. Results represented as means ± standard error (n = 90)

Parameters	Control (a)	Feeding machine noise (b)	Highway noise (c)	Level of significance ab	ac	bc
Egg weight (g)	63.60 ± 0.90	62.30 ± 0.88	56.91 ± 1.80	N	**	*
Deformation (millimicrons)	15.31 ± 1.09	17.09 ± 1.22	26.60 ± 1.31	N	**	**
Shell thickness (mm)	0.363 ± 0.45	0.352 ± 0.50	0.313 ± 0.52	N	**	**
Shell weight (g)	6.51 ± 0.16	5.80 ± 0.40	4.00 ± 0.26	N	**	*
Percent shell (%)	9.84 ± 0.44	9.35 ± 0.53	7.02 ± 0.41	N	**	**
Meat and blood spots (%)	5.81 ± 1.04	14.21 ± 1.46	22.00 ± 1.61	**	***	**

* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$
N : non significant

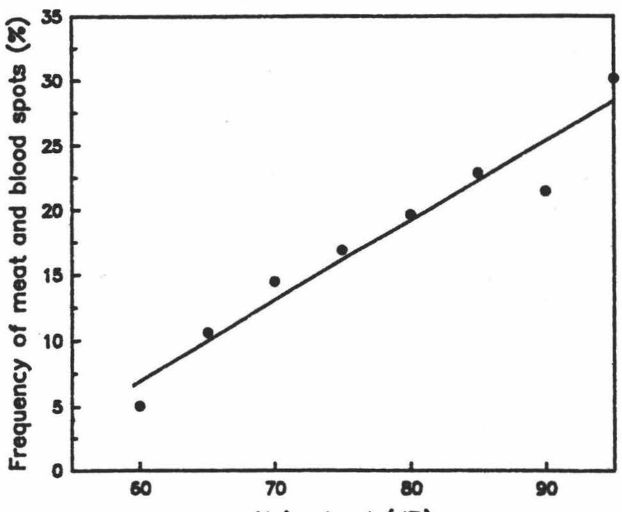


Figure 3.1. : Frequency of meat and blood spots and noise level (60 - 95dB) in eggs produced by hens loaded with highway noise. Results represented as means ± standard error (n = 90).

3.1.3. Behaviour

3.1.3.1. Comfort behaviour

Head shaking

Noise level affected head shaking frequency. Significant differences between groups were observed, the frequency of head shaking in the group treated with highway noise was reduced (4.8 ± 1.3) compared to the hens in the control group (14.15 ± 1.54), while those in the group exposed to feeding machine noise exhibited an intermediate frequency (figure 3.2.).

Body shaking

A significant change was observed in body shaking. Body shaking in control group [a] was higher than in the group loaded with highway noise [c]. Although there was a difference between groups [a] and [b], it was not significant (figure 3.2.).

Wing/leg stretching

Wing/leg stretching occurred at a frequency of approximately (3.35 ± 0.74) counts per hour in the control group. The noise level of the highway had a greatly affect on wing/leg stretching. Although the noise of the feeding machine also had an effect on wing/leg stretching, the changes were not significant. The time of day also affected the incidence of wing/leg stretching (table 3.4). At 8.00 h a slightly increased activity could be observed. At 10.00 h this behaviour trait decreased, followed by another increase of frequency around 14.00 h (5.9 ± 0.99), and a decrease towards the end of the light period (3.1 ± 0.81) (group [a]).

Figure 3.3. shows the influence of noise on the time spent on wing/leg stretching. A shorter time was spent on this activity in group [c] than in group [b].

The registrations indicated that the control group displayed a higher degree of wing/leg stretching behaviour than the other groups.

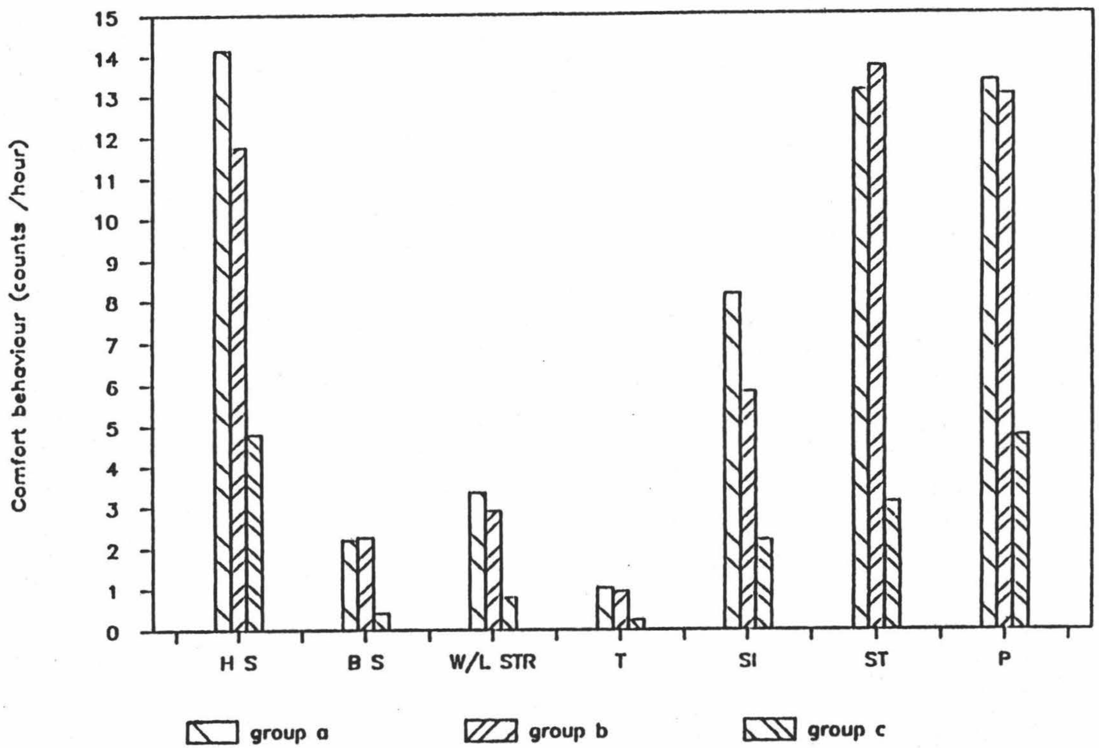


Figure 3.2. : Comparison between seven comfort behaviours (activities counts/hour) of control group (group a), hens treated with feeding machine noise (group b) and highway noise (group c) per one hour of observation (n = 30)

Head shaking   Body shaking   Wing/leg stretching   Turning   Sitting   Standing   Preening

Table 3.4 : Means and standard error of the number of times per hour of activities (wing/leg stretching and preening) between 08.00 h to 18.00 hours by 30 hens

	Wing/leg stretching behaviour						Preening behaviour					
	Observation hour						Observation hour					
Groups	08.00	10.00	12.00	14.00	16.00	18.00	08.00	10.00	12.00	14.00	16.00	18.00
Control (a)	4.45 ± 1.0	2.1 ± 0.5	5.7 ± 0.90	5.91 ± 0.99	4.00 ± 0.69	3.10 ± 0.81	11.30 ± 0.98	5.31 ± 0.62	10.9 ± 1.39	8.3 ± 1.82	7.4 ± 0.85	5.1 ± 0.85
Feeding machine noise (b)	4.20 ± 0.61	2.20 ± 0.47	5.90 ± 0.95	3.21 ± 0.82	2.20 ± 0.45	2.3 ± 0.50	10.60 ± 0.79	5.20 ± 0.83	7.30 ± 0.9	7.10 ± 1.32	8.20 ± 1.12	5.20 ± 0.94
Highway noise (c)	1.65 ± 0.46	0.75 ± 0.25	1.70 ± 0.62	1.30 ± 0.30	0.95 ± 0.22	1.90 ± 0.48	5.10 ± 0.68	2.40 ± 0.46	4.30 ± 4.42	4.10 ± 0.76	1.50 ± 0.46	4.50 ± 0.86

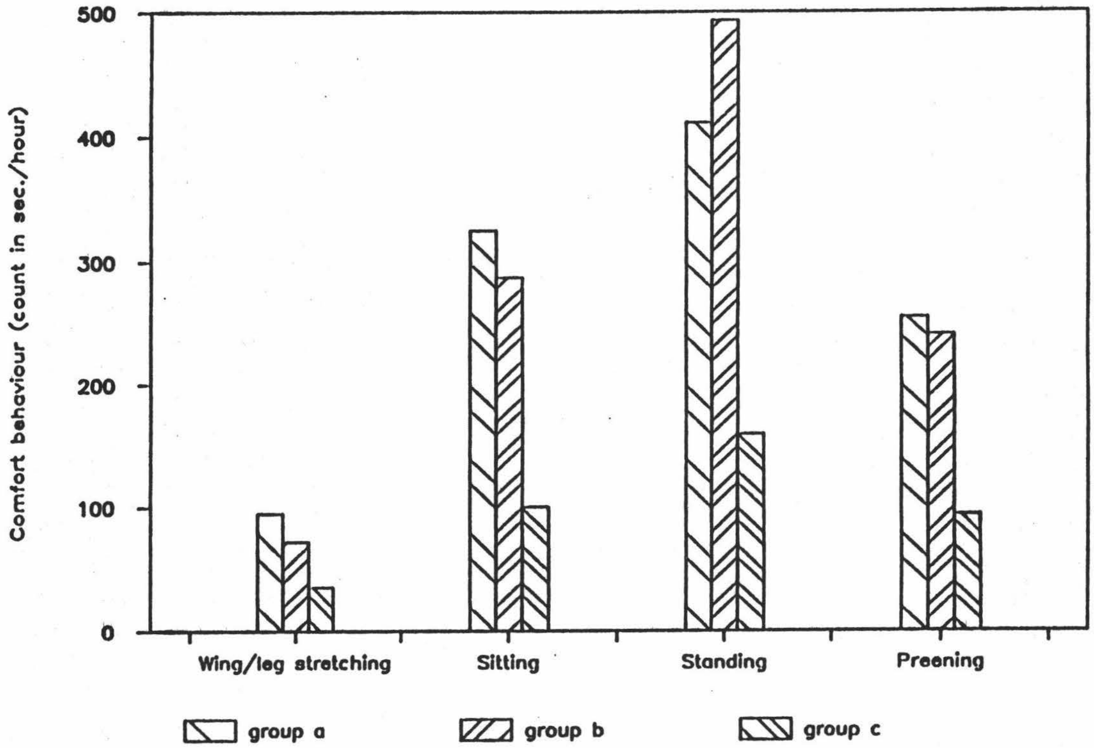


Figure 3.3. : Effect of the noise on the time spent in seconds for the comfort behaviour per one hour of observation
a = control group
b = group treated with feeding machine noise
c = group loaded with highway noise

Turning

This behaviour trait was observed very seldomly in all groups. However, the noise level did affect the turning behaviour (figure 3.2.). There was a clear decrease of the activity in group [c] (0.25 ± 0.01) ; hens in the control group turned on average (1.03 ± 0.97) times per 60 minutes while the hens in group [b] performed this activity only (0.95 ± 0.19) times/hour.

Sitting

Comparing the average counts per hour in which the activity occurred, hens in the group treated with highway noise showed sitting behaviour less (2.2 ± 0.68) than the control group (8.15 ± 1.11). These differences were significant.

There were major differences between groups in the time spent for sitting activity. The longest time spent for the activity was observed in the control group with (325.15 ± 24.16) seconds per hour, whereas group [c] had the shortest time with (100.4 ± 4.41) seconds per hour (figure 3.3.).

The differences between groups at specific times of the day were found to be significant. One hour after 'light switched-on' nearly all the hens in the control group were sitting in the corner of the cages. At midday, hens were sitting again and almost two hours before the 'light switched-off' the hens again used the corner for sitting (table 3.5).

Standing

The results are presented as mean counts of standing behaviour per 60 minutes.

In control group [a] the activity was much higher than in group [c]. In group [b] the time count per hour for standing was nearly the same as in group [a]. The results indicated that the time spent was 411 seconds in the control group compared to 159.15 seconds / hour of observation in group [c] (figure 3.3.).

These experiments also aimed at finding whether there are differences between the groups at the different times of day. It was found that in groups [a] and [b] there were two daily peaks (table 3.5). These peaks occurred in the morning (08.00 h) and at midday (12.00 h), and then declined steadily throughout the day. However, group [c] usually peaked at midday only. The regression analysis relating to the control group showed that this decline was significant ($r = 0.70$; $p < 0.05$) and could be described by the formula:

$$\text{Standing behaviour (counts/hour)} = 13.86 + (-0.46) \times \text{time}$$

Table 3.5 : Means and standard error of the number of times per hour of activities (sitting and standing) of 30 hens between 08.00 to 18.00 hours.

	Sitting behaviour						Standing behaviour					
	Observation hour						Observation hour					
Groups	08.00	10.00	12.00	14.00	16.00	18.00	08.00	10.00	12.00	14.00	16.00	18.00
Control (a)	3.5 ± 0.48	2.1 ± 0.52	3.7 ± 0.55	2.1 ± 0.40	2.9 ± 0.52	5.1 ± 0.942	9.8 ± 5.5	7.15 ± 0.83	10.15 ± 1.3	9.25 ± 0.8	7.11 ± 1.20	3.5 ± 0.49
Feeding machine noise (b)	6.15 ± 1.16	6.25 ± 0.22	10.1 ± 1.12	7.3 ± 3.86	5.6 ± 0.90	3.2 ± 0.45	8.3 ± 1.15	5.1 ± 0.82	9.1 ± 5.0	6.5 ± 0.95	5.5 ± 0.8	4.9 ± 0.82
Highway noise (c)	1.35 ± 0.36	0.85 ± 0.19	1.2 ± 0.26	1.6 ± 0.33	1.27 ± 0.34	2.95 ± 0.57	3.6 ± 0.64	2.5 ± 0.54	7.4 ± 0.84	5.2 ± 0.72	3.7 ± 0.62	4.5 ± 0.6

Preening (feather cleaning)

Noise had a distinct effect on the preening behaviour. Concerning the cleaning of the feathers a slight but non-significant difference was noticed between the control group [a] and group [b]. However, there were significant differences between the control group and the group exposed to highway noise [c].

The amounts of time spent preening in each group are shown in figure 3.3. It can be seen that the time spent in the control group is higher than in the other groups.

Preening times showed a strong daily rhythm with a tendency for more preening to occur at the beginning of the day. More time was spent for preening during the first hours after the light was switched on (11.3 ± 0.97) and a shorter time at 18.00 h (table 3.4).

3.1.3.2. Maintenance behaviour

Feeding behaviour

A large amount of time was spent for feeding behaviour. The results showed that feeding behaviour actually was the most common activity. The control group spent more time feeding than any of the other groups. The effect of noise stress on the feeding behaviour is shown in table 3.6. The total number of feeding bouts and the number of hens feeding together were highest in the control group and lowest in groups [b] and [c]. Nearly all of these differences were significant as was shown by the t-test.

In the case of feeding activity a difference also existed at the different times of day. In the control group at 08.00 h, there was a great activity (23.9 bouts/h), followed by a quiet period at 10.00. There was a frequency increase around the middle of the day, and a decline during the evening, with the lowest frequency observed at 18.00 h (11.34 bouts per hour). However, noise stress had a marked effect on the diurnal feeding behaviour. In group [c], a high frequency was recorded at 08.00, 12.00 and 16.00 h, and a lower one during noise exposure time.

Table 3.6 : Means and standard error of the feeding activities per hour for hens under noise stress (n = 60) in course of six observation hours

Observation hour	Parameters	Control group (a)	Highway machine noise (b)	Highway noise (c)	Level of significances		
					ab	ac	bc
08.00	No. of bouts	23.9 ± 2.55	19.3 ± 2.4	14.6 ± 16.8	*	***	**
	Time spent in sec.	1 053 ± 43.9	1 011 ± 54.6	953.6 ± 26.8	**	***	***
	Hens feeding together	4.2 ± 0.17	3.8 ± 0.54	2.9 ± 0.34	N	*	N
10.00	No. of bouts	18.2 ± 2.44	15.7 ± 1.7	4.8 ± 1	*	***	***
	Time spent in sec.	710 ± 41	692 ± 61	375.5 ± 8.6	*	***	***
	Hens feeding together	2.2 ± 0.27	2.9 ± 0.4	3.3 ± 0.39	N	*	N
12.00	No. of bouts	37.4 ± 5.12	33.34 ± 2.3	17.4 ± 0.87	*	***	***
	Time spent in sec.	1 237 ± 79	1 021 ± 42	1 070 ± 24	**	**	*
	Hens feeding together	3.9 ± 0.19	3.2 ± 0.6	3.9 ± 0.82	N	N	N
14.00	No. of bouts	28.4 ± 4.19	25.3 ± 1.8	9.4 ± 0.97	*	***	***
	Time spent in sec.	1 015 ± 69	992 ± 50	633 ± 34	**	***	***
	Hens feeding together	3.5 ± 0.33	3.2 ± 0.46	1.9 ± 0.35	N	*	*
16.00	No. of bouts	20.5 ± 1.20	16.1 ± 1.7	11.2 ± 1.14	**	***	**
	Time spent in sec.	782.8 ± 37.4	755 ± 57	856.8 ± 38.9	**	**	*
	Hens feeding together	3.2 ± 0.48	2.8 ± 0.28	2.2 ± 0.29	N	*	N
18.00	No. of bouts	11.34 ± 2.69	10.9 ± 3.7	3.6 ± 0.92	N	***	**
	Time spent in sec.	439.5 ± 12.9	409.3 ± 36.7	381.6 ± 10.28	**	***	**
	Hens feeding together	1.5 ± 0.29	2.3 ± 0.21	3.1 ± 0.28	N	**	N

* < p 0.05
** < p 0.01
*** < p 0.001
N non significant

Drinking behaviour

There are differences in drinking behaviour between the control group and the other groups. Noise stress affected both the drinking activity itself and its diurnal pattern, resulting in two peaks - one in the morning and one at 12.00 h - and a more quiescent period in the evening (for groups [a] and [b]). In the group exposed to highway noise, on the other hand, the two peaks occurred at 12.00 and 16.00 h. This is obviously due to the specific noise regime.

The noise level had an effect on the average number of peaks of the activity. The number of peaks at the nipples was lower in the group loaded with highway noise compared to the control group. The mean values and standard errors for the peak numbers during five hours of observation are shown in table 3.7.

3.1.3.3. Hen position

Of the factors considered in the analysis, the levels of the feeding machine and highway noise had the most pronounced effect on the position of the hens. Table 3.8 shows the effect of noise on the hens' position. The results indicated that also the time of day had a significant effect on the hens' position in the different groups. The results indicated that, in the morning, the hens in control group [a] spent more time per hour in the front half of the cage than those in groups [b] and [c]. Specific data for the control and for groups [b] and [c] were (19.53 ± 1.67), (17.6 ± 2.26) and (9.53 ± 5.92), respectively. Represented as percentages, these times were 65.1, 58.66 and 31.76 % of total time, for groups [a], [b] and [c] respectively.

During the afternoon the hens preferred to spend more time in the rear rather than in the front of the cage and the differences were not significant, except for the control group.

The results showed that considerably more time is spent by the hens in the front half of the cage in the morning than in the afternoon; this observation was valid for all the groups.

Table 3.7 : Effect of highway and feeding machine noise on drinking activity per hour in the course of six observations (n = 60). Data represented as means ± standard behaviour

Observation hour	Parameters	Control group (a)	Feeding machine noise (b)	Highway noise (c)	Level of significance ab	ac	bc
08.00	No of pecks	7.1 ± 0.64	7.5 ± 1.56	3.5 ± 0.62	N	**	**
	Time spent in sec.	165.13 ± 12.42	185.6 ± 13.33	140 ± 19.1	**	***	***
10.00	No of pecks	6.43 ± 0.15	4.5 ± 0.72	4.0 ± 0.73	**	**	N
	Time spent in sec.	151.9 ± 14.46	149 ± 11.79	126.9 ± 3.7	N	**	*
12.00	No of pecks	10.33 ± 1.52	8.2 ± 1.65	7.6 ± 0.66	*	*	N
	Time spent in sec.	214.3 ± 31.6	221 ± 17.69	240 ± 16.72	N	**	**
14.00	No of pecks	7.36 ± 1.15	6.31 ± 0.85	3.7 ± 0.8	N	**	*
	Time spent in sec.	160.1 ± 7.85	178 ± 18.5	100 ± 5.5	*	**	***
16.00	No of pecks	4.46 ± 0.51	4.95 ± 0.63	5.2 ± 1.4	N	N	N
	Time spent in sec.	131.9 ± 6.1	1.47 ± 7.6	220 ± 17.6	**	***	***
18.00	No of pecks	1.13 ± 0.23	2.6 ± 0.47	4.3 ± 1.11	*	**	*
	Time spent in sec.	81.83 ± 5.7	91.11 ± 5.46	131 ± 3.17	**	***	***

* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$
N non significant

Table 3.8 : Means of number of moves (counts/hour) and hens' position in the morning and afternoon under noise stress (n = 30)

Groups	Morning		Afternoon		Number of moves	
	Front	Rear	Front	Rear	Morning	Afternoon
Control (a)	19.53 ± 1.67	10.47 ± 1.51	14.6 ± 2.1	15.4 ± 2.19	42.4 ± 3.4	29.27 ± 3.81
Feeding machine noise (b)	17.6 ± 2.26	12.4 ± 1.7	13.3 ± 2.3	16.6 ± 2.6	35.6 ± 3.9	26.73 ± 2.62
Highway noise (c)	9.53 ± 5.92	20.47 ± 2.44	7.13 ± 1.21	22.93 ± 2.17	26.53 ± 3.88	13.87 ± 3.21

3.1.3.4. Agonistic behaviour

Agonistic behaviour as observed between 24 and 60 weeks of age was influenced both by the noise of a highway and by feeding machine noise.

Hens in control group [a] exhibited significantly less aggressive acts than those in the groups treated with feeding machine [b] and highway noise [c]. Agonistic activities (floor, cage, trough and feather pecking and pushing) occurred more frequently in groups [b] and [c]. For instance, mean frequencies of floor pecking were 5.32 and 10.6 counts per hour for groups [b] and [c], respectively. The tendency is toward fewer counts per hour for floor pecking behaviour in control group [a] (3.2 counts per hour).

In general, pecking accounted for 80 % of all agonistic behaviour recorded during experimental work and active counts (group [a]); frequencies were 3.3, 11.0, 13.6 and 7.6 per hour for pecking of the floor, the cage, the trough and the feathers respectively. Pushing movements increased when the noise generated forced the hens to change its position by means of pushing their neighbours aside (figure 3.4).

The differences in noise level (dB) influenced the frequency of cage and trough pecking. These effects are shown clearly in figure 3.5. Relative frequencies of cage as well as trough pecking were found to be higher with increasing noise level. However, correlation coefficients for both pushing and floor pecking versus noise level were not significant, as shown in table 3.9.

3.1.3.5. Abnormal behaviour

A total of 5 activities was observed, of which the following were performed significantly ($p < 0.01$) less often in the control group: feather pecking, cannibalism, jumping more than once, moving randomly and head pecking.

The results are presented as average counts of abnormal behaviour per 60 minutes and are related to the noise level. They are given in detail in figure 3.6. Paired t-tests based on these data were carried out to determine whether differences were significant. The results showed that the noise level was a distinct factor causing abnormal behaviour.

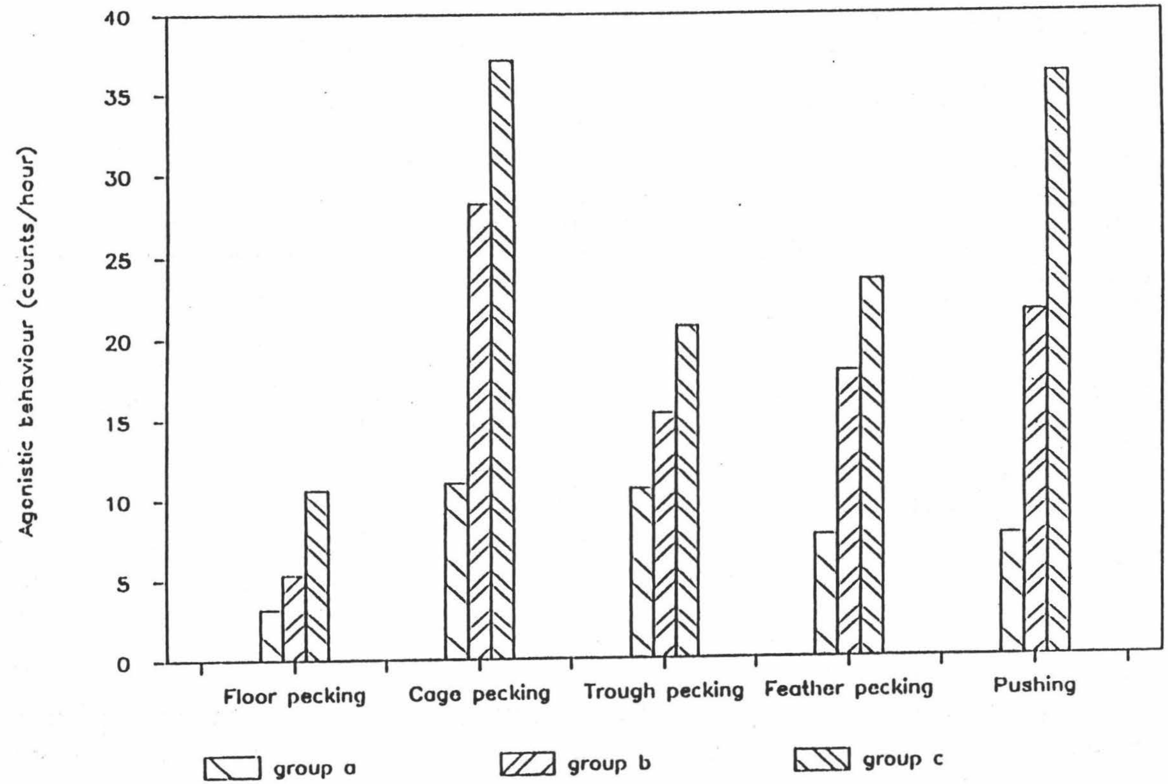


Figure 3.4 : Mean performances of agonistic behaviour counts per hour affected by noise of feeding machine and highway noise
a = control group
b = group subjected to feeding machine noise
c = group subjected to highway noise

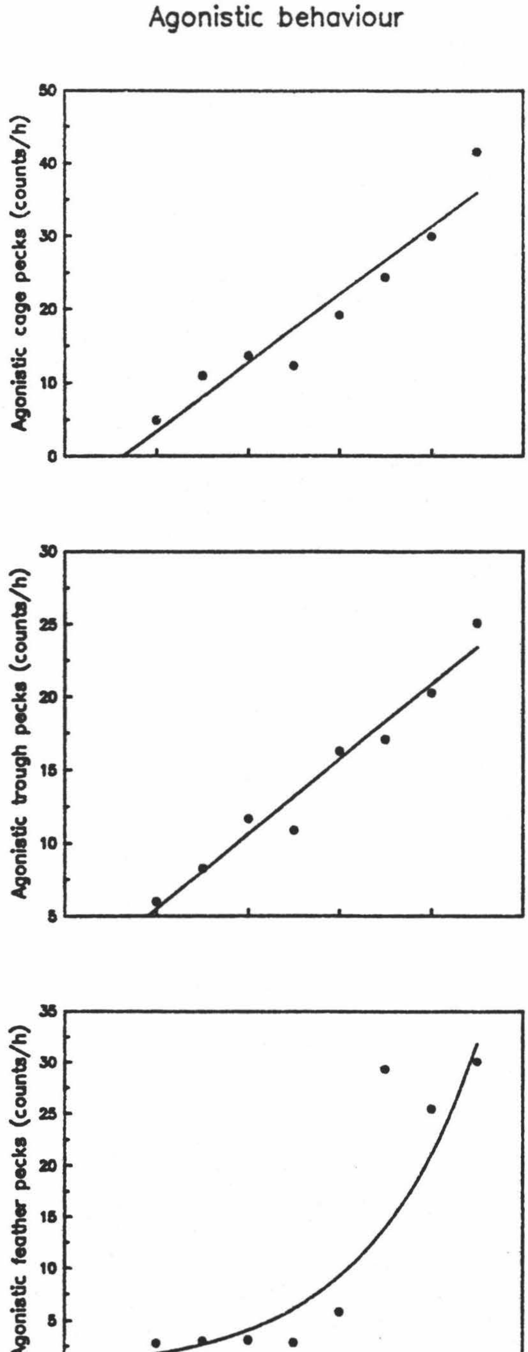


Figure 3.5. : Effect of different highway noise levels on the agonistic behaviour (counts/hour) of 30 hens

Feather pecking

Noise of both highway and feeding machine were strong stress factors ; in the presence of this acoustic background the hens exhibited an increase of feather pecking.

There is a progressive increase in the average incidence of feather pecking with rising noise level (figure 3.5). Regression analysis showed that this increase was significant ($r = 0.91$, $p < 0.01$), the regression equation being

$$\text{feather pecking} = 107.04 - 3.44\ (\text{dB}) + 0.03\ (\text{dB})^2$$

Table 3.9. Regression and correlation coefficients for agonistic behaviour versus various noise levels (n = 30)
Regression equation: agonistic behaviour = A + B + . noise level (60 - 95 dB)

Agonistic behaviour	A	B	r	Level of significance
Floor pecking	-0.77	0.050	0.33	N
Cage pecking	-52.43	0.930	0.96	**
Trough pecking	-25.26	0.510	0.97	**
Pushing	18.89	-0.150	0.22	N

Cannibalism

Noise had an extremely pronounced effect on the behaviour of the hens and stimulated them to cannibalism and aggression. The data indicated that highway noise (group [c]) increased the incidences of cannibalism (7.3 ± 0.87) as compared with the control group (1.3 ± 0.14). In the group treated with feeding machine noise, the frequency of cannibalism was (2.4 ± 0.58) times/h.

Jumping more than once

The groups loaded with highway and feeding machine noise exhibited significant changes. Counts of jumping were higher (10 ± 0.96) for hens housed in group [c] than for those housed in groups [b] and [a]. The means and significance values of these results are given in figure 3.6.

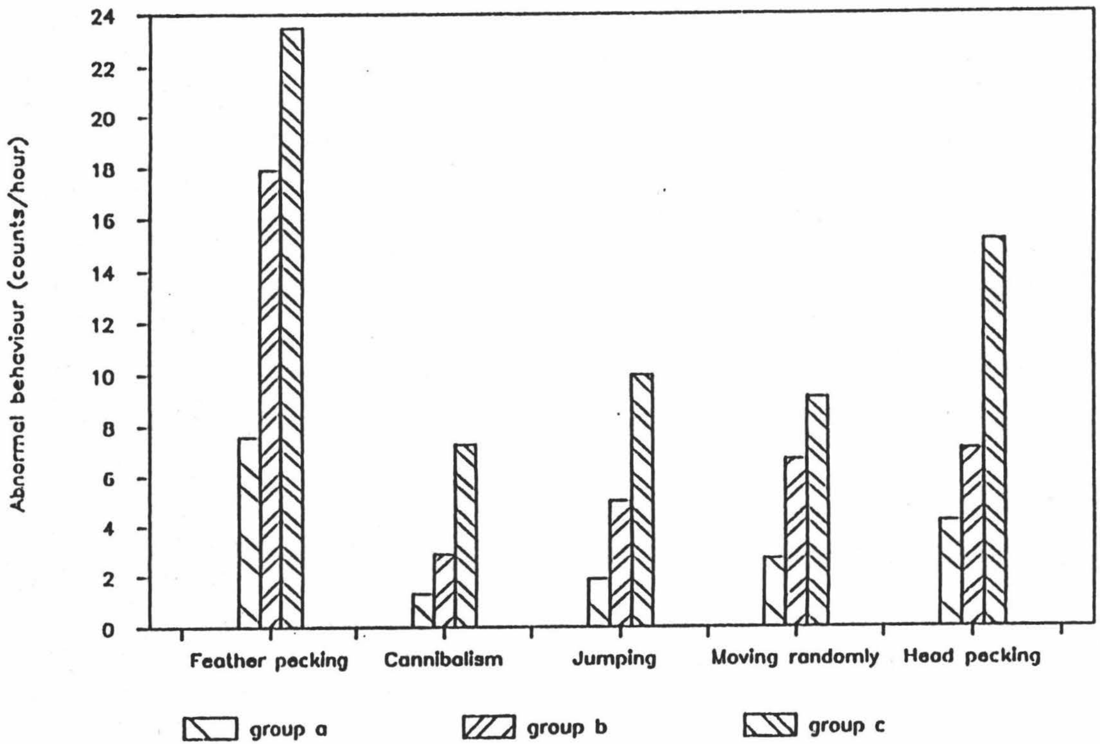


Figure 3.6. : The average count of abnormal behaviour per 60 minutes related to the noise stress
a = control group
b = group treated with feeding machine noise
c = group loaded with highway noise

Moving randomly

Noise influenced the frequency of random movements made by the hens inside the cages. These movements caused disturbance to the other hens. The results indicated that the hens in groups [b] and [c] made more random moves than those in the control group.

The second purpose of this section is to determine whether there is a relation between different noise levels and random movement and feather pecking behaviour. The tests carried out established that there was a significant effect of noise only on feather pecking and random movements, and linear regression ($r = 0.97$; $p < 0.01$) demonstrated a consistent increase (figure 3.7).

It is interesting to note that the optimum noise level inside the poultry houses (when the feeding machine was not in operation) was 55 dB.

Head pecking

The lowest frequency of head pecking was noted in the control group (4.2 ± 0.18). Increasing incidence of head pecking was observed with rising noise level. The average head pecking frequency in group [b] was (7.1 ± 0.99) ; in group [c] it was (15.2 ± 1.08).

The differences between the groups were significant. Pecking at the head made up approximately 19.0 %, 8.9 % and 5.2 % of the total pecks which were directed to the body parts in groups [c], [b] and [a] respectively.

3.1.4. Economic parameters

The results showed that noise stress had affected eggs income. As mentioned higher, cage profit is based on the balance between the input of feed and output of eggs of all the hens in a cage. The equation used for determining cage profits reads

Cage profits = gross returns/cage - total costs/cage

Following cage profits were calculated :

1. Control group
Gross returns/cage = receipts from the scale of the egg + cull hens price
Gross returns/cage = 3 464.21 BF
Total costs/cage = feed cost + rearing cost + fixed costs
Total cost/cage = 3 406.22 BF
Cage profits = 3 464.21 - 3 406.22 = 57.99 BF

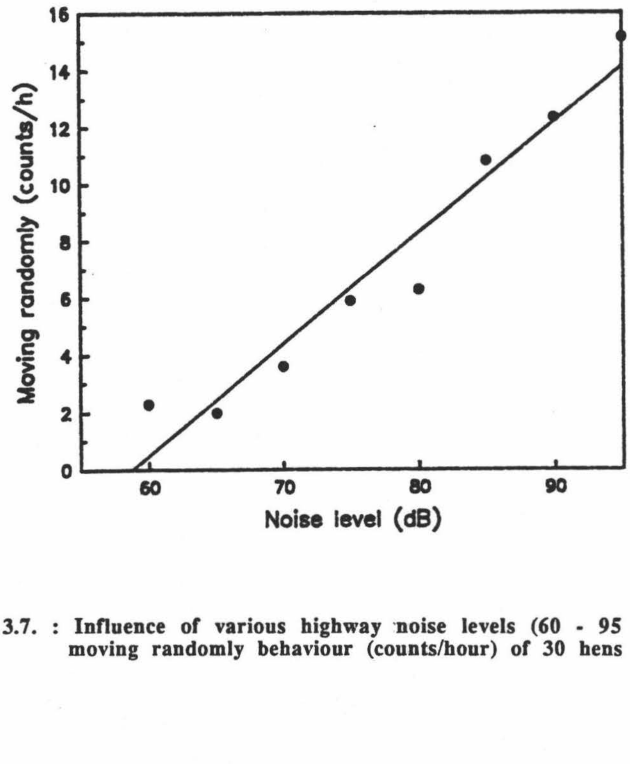


Figure 3.7. : Influence of various highway noise levels (60 - 95 dB) on the moving randomly behaviour (counts/hour) of 30 hens

2. Group treated with feeding machine noise

Gross returns/cage = 3 461.17 BF

Total costs/cage = 3 408.06 BF

Cage profits = 3 461.17 - 3 408.06 = 53.11 BF

3. Group loaded with highway noise

Gross returns/cage = 2 938.76 BF

Total costs/cage = 3 106.6 BF

Cage profits = 2 938.76 - 3 106.6 = -167.24 BF

3.1.5. Mineral contents of the egg shell

Calcium

Shell calcium, expressed as milligrams per gram of shell, was recalculated as a percentage.

Calcium levels were significantly lower in eggs produced by hens treated with highway noise stress compared with the eggs from the control group (34.49 ± 0.71 vs. 29.63 ± 0.48).

The calcium percentage was not affected by feeding machine noise stress ; the existing difference as compared with control was not significant.

Magnesium

Magnesium levels declined in group [c] when compared to control group [a] whereas group (0.44 ± 0.09 [b]) was situated in between (0.50± 0.06[a]) and (0.30 ± 0.01[c]). The differences between the groups were significant ($p < 0.05$).

Phosphate

The inorganic phosphate level of eggs laid by hens treated with highway noise (0.037 ± 0.20, group [c]) was lower than in the control group (0.048 ± 0.10[a]); the difference was significant ($p < 0.05$).

The phosphate level in eggs produced by group (0.045 ± 0.15 [b]) hens - which were exposed to feeding machine noise - exhibited only minor and non-significant differences with those of the control group.

The results are summarized in figure 3.8. Egg shells from the control group were thicker and had higher calcium, magnesium and phosphate contents when compared to shells from hens exposed to both feeding machine and highway noise stress.

3.1.6. Feather condition

Table 3.10 shows all results of the scoring of plumage condition of hens belonging to the three groups. In the control room the scores were generally higher in most of the measurements made. For the control group, the average scores given for each of the five individual body parts as in the single-score method differed significantly from the results obtained for the other groups. Plate 3.1 shows another comparison between control and hens treated with noise.

The results showed that there were differences between control and the feeding machine noise treatment, i.e. group [b]. Feather condition for the whole body as a sum of the scores for individual body parts as well as the single score was significantly inferior ($p < 0.01$). Looking at individual parts, it can be seen from the table 3.10 that only the scores for plumage condition of the neck, back, and wing were not significantly different in group [b] compared with control group [a].

Feathering condition in the group treated with feeding machine noise was better than in the group which was exposed to highway noise.

The results indicated that the most affected part of the body was the breast for the whole group.

It was observed that the plumage condition was on the whole significantly lower in response to noise stress. It was found that noise produced by the feeding machine and a highway respectively contributes by 8.45 % and 51.00 % to feather deterioration.

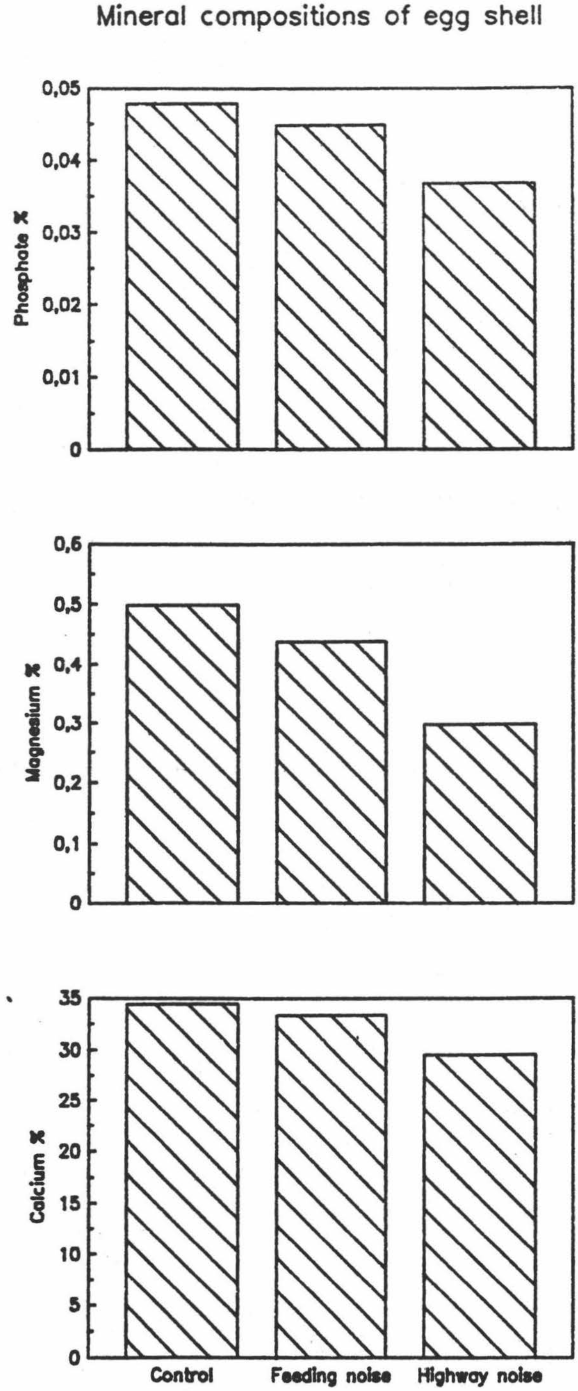


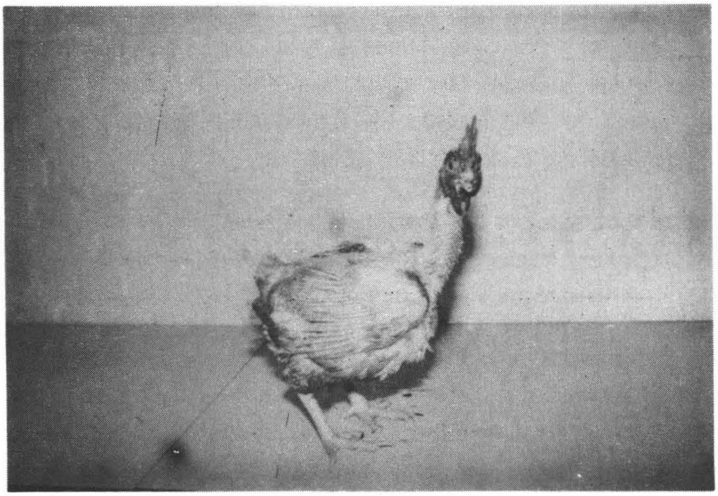
Figure 3.8. : Effect of highway noise stress on the mineral contents of egg shells (n = 100)

Table 3.10 : Means (± standard error) for the plumage condition measured for hens under stress of feeding machine and highway noise (n = 90)

Body part	Control	Feeding machine noise	Highway noise	Level of significance		
	(a)	(b)	(c)	ab	ac	bc
Neck	3.54 ± 0.06	3.32 ± 0.90	1.56 ± 0.18	N	***	***
Breast	2.81 ± 0.91	2.51 ± 0.14	1.10 ± 1.09	*	**	**
Back	3.18 ± 0.07	3.08 ± 0.09	1.45 ± 0.20	N	**	**
Wing	3.53 ± 0.20	3.30 ± 0.20	1.60 ± 0.98	N	**	***
Tail	3.02 ± 0.16	2.77 ± 0.17	1.20 ± 0.15	*	***	**
Total	16.14 ± 0.27	14.98 ± 0.39	6.91 ± 0.65	**	***	***
Single	16.60 ± 0.34	14.36 ± 0.71	5.50 ± 1.02	**	***	***
Average	16.37 ± 0.30	14.68 ± 0.50	6.20 ± 0.80	**	***	***

* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$
N non significant

1.



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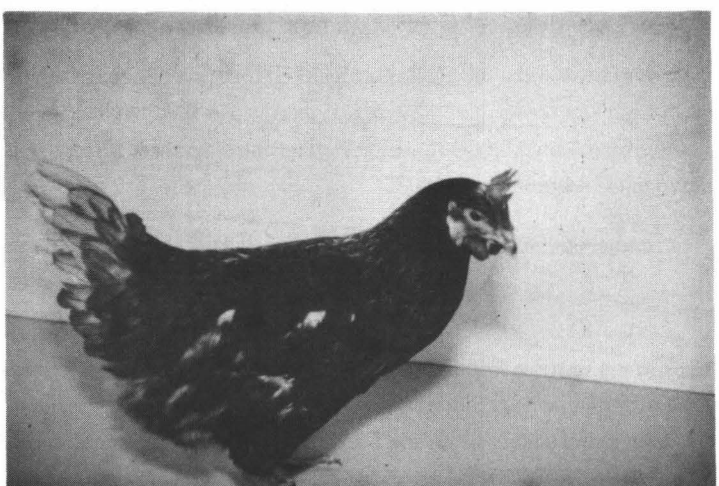

Plate 3.1. Feather condition of hens under highway noise stress and control groups
1. Plumage condition of a hen under stress with a score of 1 point
2. Plumage condition of a hen under no stress with a score of 19 points

3.1.7. Corticosterone levels in the hens' plasma

The concentrations of corticosterone hormone for all three treatment groups are depicted in table 3.11. There were differences between the corticosterone values from the three groups, and the t-test was performed to compare between them. The results showed that hens loaded with highway noise had markedly higher ($p < 0.001$) corticosterone levels than the control.

The mean concentrations ($\pm$ SE) of the blood samples were also higher in hens exposed to feeding machine noise (2.93 ± 0.09), while the control level was (2.2 ± 0.02) ; this difference was significant ($p < 0.05$).

Corticosterone concentrations in hens under stress increased as time progressed and remained high until the age of 46 and 52 weeks for hens exposed to feeding machine and highway noise respectively. It seems that the results of corticosterone concentration in the control group stayed nearly constant during the research period. Hormone concentrations in hens exposed to highway and feeding machine noise at different ages relative to housing and comparison with control are shown (table 3.12).

The regression lines reflect the effect of age on hormone concentration (table 3.13) Generally the increase of age results in an increase of hormone concentration.

The results indicated that the corticosterone concentration of hens in the group treated with highway noise increased significantly ($p < 0.01$) as the level of noise increased from 60 upto 95 dB (figure 3.9). The correlation coefficient was positive as shown in the regression equation:

$$\text{corticosterone concentration} = -11.33 + 0.212 \,.\, \text{noise level (dB)}$$

$$r = 0.98$$

Changes in the serum corticosterone concentration in hens were monitored in response to different periods of exposure to feeding machine noise. Correlation coefficients between exposure times and hormone level in plasma were high and significant ($r = 0.96$, $p < 0.001$). Periods of exposure to feeding machine noise were designed to last for 10, 20, 30, 40, 50 and 60 minutes in order to measure the level of hormone in each period (figure 3.9). It was observed that the corticosterone concentration before exposure to feeding machine noise was low, but during the exposure period a high level of hormones was found. This phenomenon occurred only in the first weeks of the experiment, the laying hens adapting to the noise produced by the feeding machine. The positive correlation coefficient (r = 0.96) indicated that response was greater with longer exposure periods. Means and standard error of corticosterone hormone (ng/ml) in plasma was 2.97 ± 0.44 (before the noise) and 4.81 ± 0.38 (after the noise).

Table 3.11. Mean corticosterone concentrations of 30 laying hens under noise stress (feeding machine and highway noise)

Treatment	Corticosterone level (ng/ml)	Level of significance ab	ac	bc
Control (a)	2.20 ± 0.02	*	***	***
Feeding machine noise (b)	2.93 ± 0.09			
Highway noise (c)	7.26 ± 0.03			

Mean plasma steroid concentration expressed as nanograms per millilitre plasma ± standard error of the mean (n = 30)

* $p < 0.05$

*** $p < 0.001$

Table 3.12. Average serum corticosterone concentrations (ng/ml) of hens at different ages. Results represented mean ± standard error (n = 30)

Weeks of age	Control (a)	Feeding machine noise (b)	Highway noise (c)
28	2.00 ± 0.10	2.00 ± 0.22	2.70 ± 0.24
34	2.00 ± 0.15	2.20 ± 0.40	3.73 ± 0.33
40	2.20 ± 0.07	3.00 ± 0.38	4.21 ± 0.48
46	2.30 ± 0.18	4.40 ± 0.90	6.25 ± 0.83
52	2.40 ± 0.08	3.40 ± 0.43	12.00 ± 0.80
58	2.53 ± 0.23	2.73 ± 0.40	10.9 ± 0.62
64	2.66 ± 0.20	2.00 ± 0.30	8.43 ± 1.44

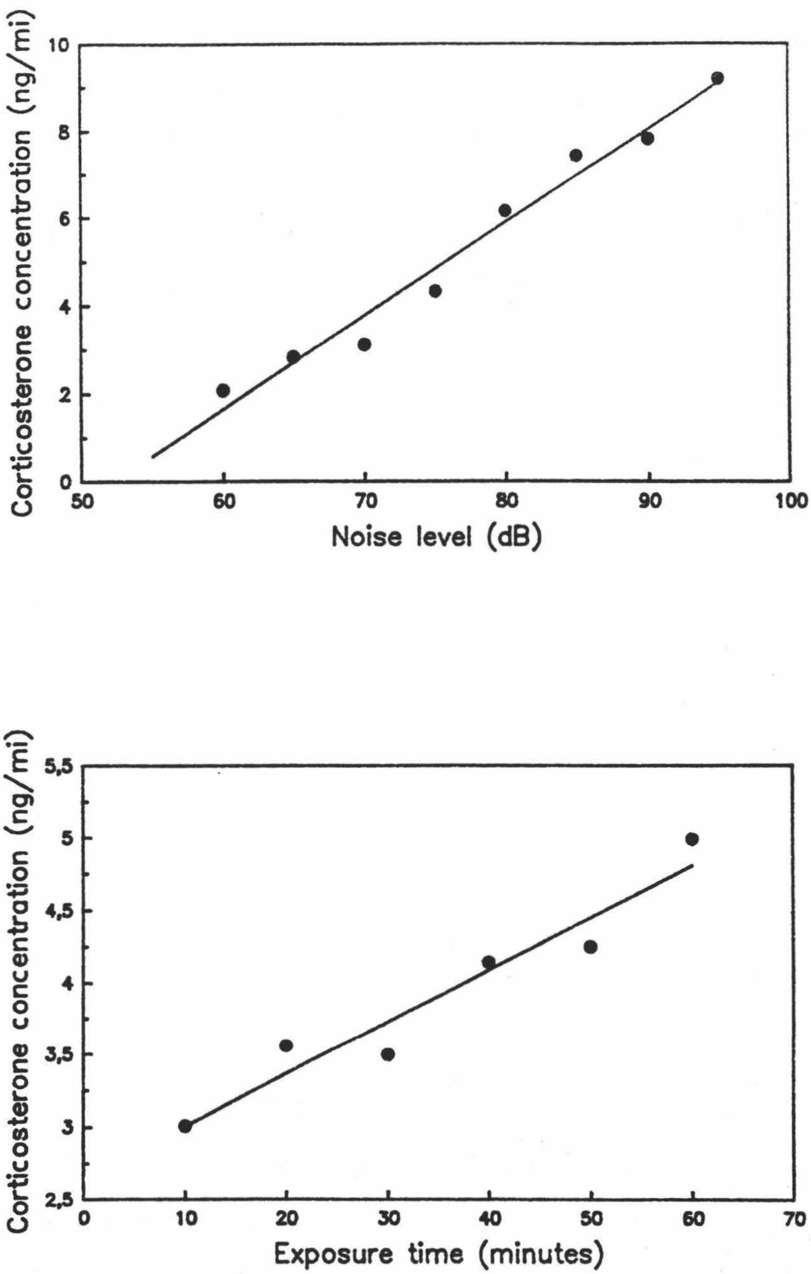

Figure 3.9. : Plasma corticosterone concentrations change in response to the level of highway noise (60 - 95 dB) [upper] and feeding machine (75 - 80 dB) noise in treatments from 10 up to 60 minutes [lower]. Samples obtained from 30 hens and results represented as means

Table 3.13: Simple correlation coefficient and regression coefficients for the corticosterone concentration (CC) in the plasma of 30 hens at different ages.(28-64weeks)

Treatments	a	+	bx			r
Control	1.41		0.02			0.98 **
Highway noise	- 3.88		0.23			0.83 *
	a	+	b.x	+	$c.x^2$	r
Feeding machine noise	- 8.54		0.52 (dB)		- 0.01 $(dB)^2$	0.86 *

3.1.8. Abnormal egg shells

The major categories of abnormality recognized are shown in table 3.14. Feeding machine and highway noise influenced both the proportion of abnormalities and the rate of production. Figure 3.10 shows the incidence of abnormal egg shells for each category collected from a noise-loaded group and the control group. Throughout their laying period, the proportion of normal eggs declined sharply in the group of pullets treated with highway noise (71.56 ± 1.11) as compared to the control group (90.16 ± 0.38). The difference was significant ($p < 0.001$) (figure 3.11). The control group showed no appreciable changes in amount of abnormal eggs. A pronounced effect of feeding machine noise on the frequency of occurrence of abnormal eggs was observed as well ; this detriment was significant when compared with the control group.

Some of the particular egg shell abnormalities increased sharply due to feeding machine and highway noise disturbance, e.g. the proportion of misshapen or other defective (plate 3.2) egg shells (soft shell, shell-less, bulgy ; see plate 3.3). The incidence of egg shells showing a chalky (plate 3.4) or brown deposit or being dusty did show changes, but these were not significant. All categories of abnormality showed consistent changes in relation to highway noise. However, the frequency of occurrence of these egg shell abnormalities were not significant (plate 3.2) in relation to the feeding machine noise.

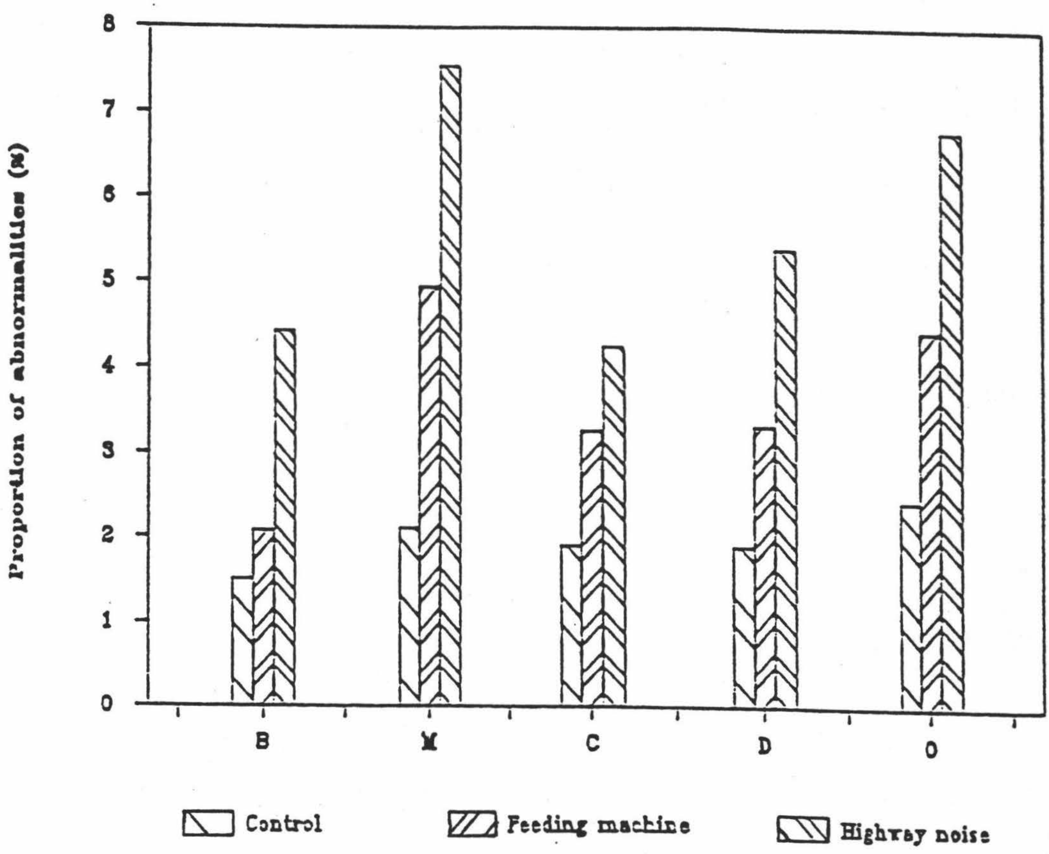

Figure 3.10 : Proportion of eggs falling into each of the categories shown in the group loaded with highway and feeding machine noise and compared with the control group. B : Brown deposit, M : Misshapen, C: Chalky, D: Dusty and O: Other defects

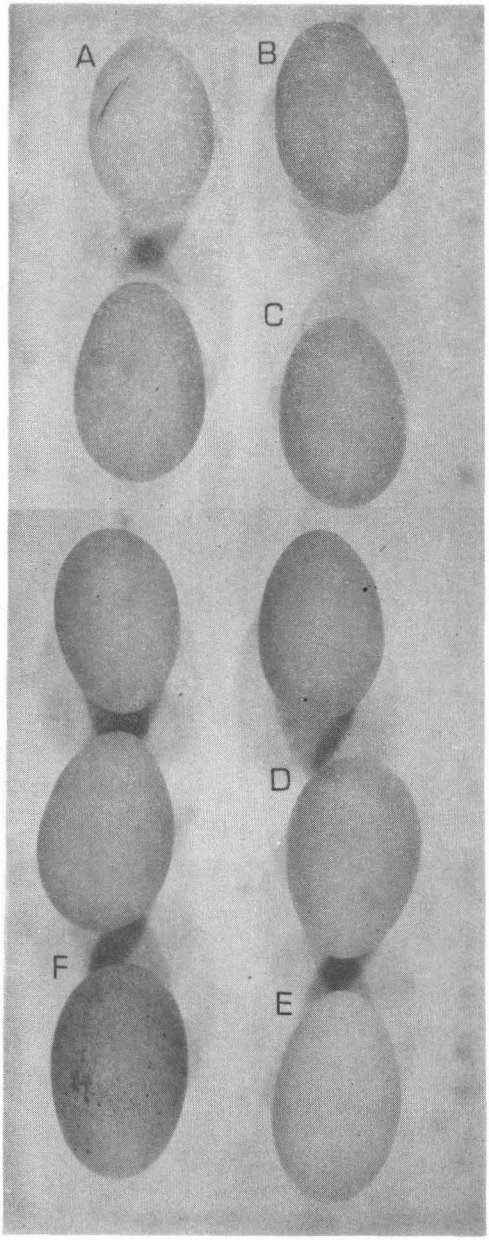

Plate 3.2 : Categories of egg shells affected by highway and feeding machine noise

A normal B Bulgy C Mishapen D Dusty E Very dusty F Brown deposit

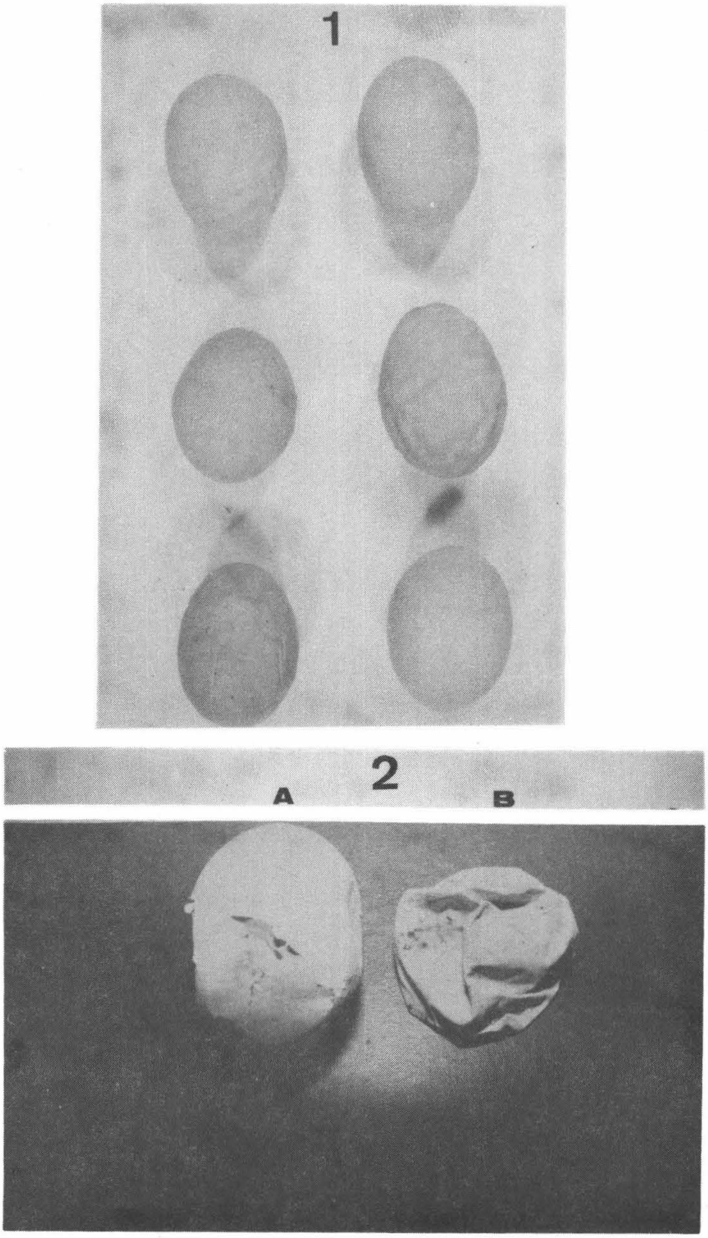

Plate 3.3 : Incidence of eggs showing abnormal shell as laid by hens exposed to highway noise

1. Bulgy egg shell
2. A) soft shell B) Shell-less

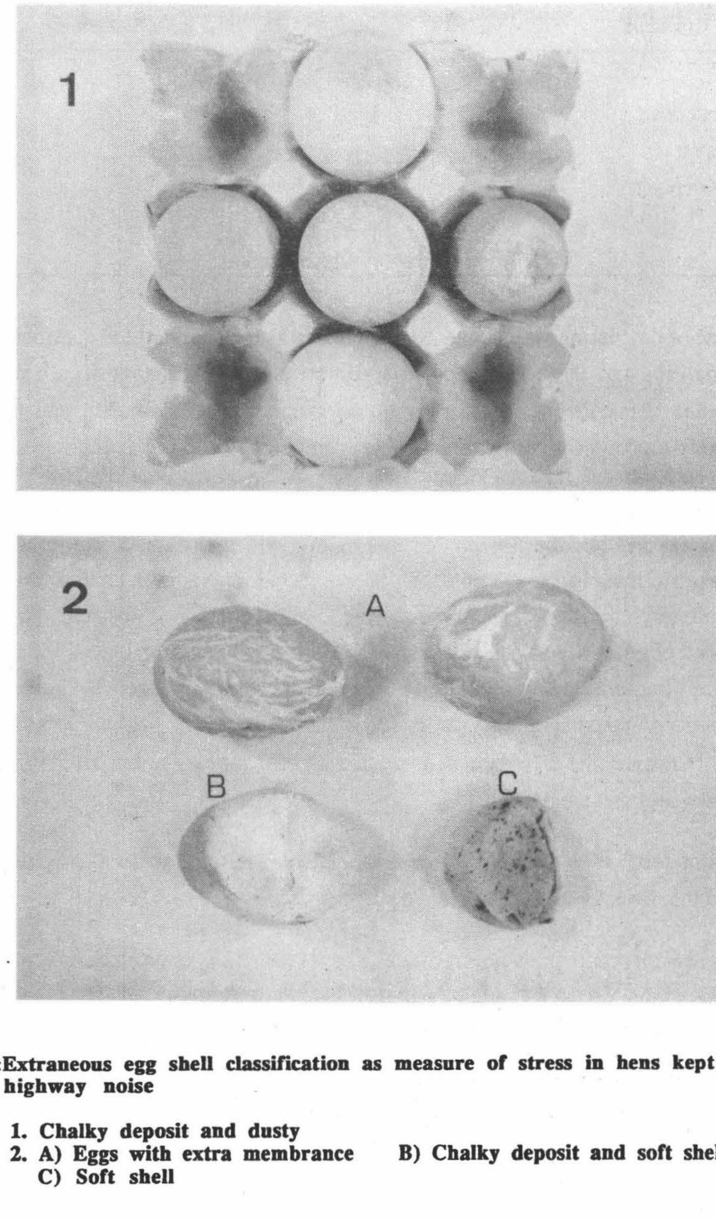

Plate 3.4 :Extraneous egg shell classification as measure of stress in hens kept under highway noise

1. Chalky deposit and dusty
2. A) Eggs with extra membrance B) Chalky deposit and soft shell
C) Soft shell

Table 3.14. List of superficial egg shell abnormalities

Normal
Brown deposit
Misshapen
Chalky deposit
Dusty
Other : "soft shell", "shell-less", "bulgy", "white-banded"

The time of day during which eggs were collected also influenced the distribution of abnormalities and the effect showed a similar pattern of change in all groups. Among the eggs collected in the morning the proportion of misshapen eggs or bulges or soft-shell eggs was higher than among those collected in the afternoon (table 3.15). The other categories of abnormality showed little diurnal variation.

For this experiment the pooled regression lines of normal and abnormal eggs against noise levels from 60 up to 95 dB are shown in figure 3.11. Furthermore, the positive relationship between noise level and proportion of misshapen eggs as well as other defects was nearly constant. This means the occurrence of abnormal eggs was directly related to the increase in noise level of highway, the correlation coefficient of misshapen egg shells for instance was very high ($r = 0.95$, $p < 0.001$). However, the difference was neither significant for the brown deposit nor for chalky and dusty egg shells.

At higher level of noise (85, 90 and 95 dB) normal egg shells decreased and reached the lowest value of 60 % at 95 dB.

The regression coefficients are statistically ($p < 0.01$) different for the normal eggs, as can be shown by the following formula:

$$\text{percentage of normal eggs} = 121.2 - 0.62 \,.\, \text{noise level (60 - 95 dB)}$$

$$r = -0.94$$

Table 3.15 : Categorisation of abnormal egg shells which were collected in the morning and afternoon from hens exposed to highway and feeding machine noise and control group (n = 90). Results represented as mean ± standard error

	Control (%)		Level of significance	Feeding machine noise (%)		Level of significance	Highway noise (%)		Level of significance
	morning	afternoon		morning	afternoon		morning	afternoon	
Brown deposit	1.1 ± 0.3	1.9 ± 0.7	N	2.3 ± 0.52	2.5 ± 0.71	N	5.6 ± 0.7	6.1 ± 1.34	N
Misshapen	3 ± 1.0	1.7 ± 0.5	*	4.7 ± 1.08	2.51 ± 0.8	**	10.5 ± 1.64	7.8 ± 1.28	*
Chalky	2.9 ± 0.36	1.5 ± 0.66	*	5.52 ± 0.83	3.12 ± 0.93	**	7.9 ± 1.3	4.5 ± 0.82	**
Dusty	1.7 ± 1.5	2.1 ± 0.9	N	3.57 ± 0.58	3.03 ± 0.73	N	6.3 ± 1.08	7.1 ± 0.71	N
Other	3.55 ± 1.7	2.22 ± 1.5	*	3.2 ± 0.46	5.3 ± 0.82	**	8.1 ± 1.52	10.9 ± 1.3	*

* $p < 0.05$
** $p < 0.01$
N non significant
other (soft shell, shell-less, bulgy, white banded)

Abnormal eggs versus highway noise level

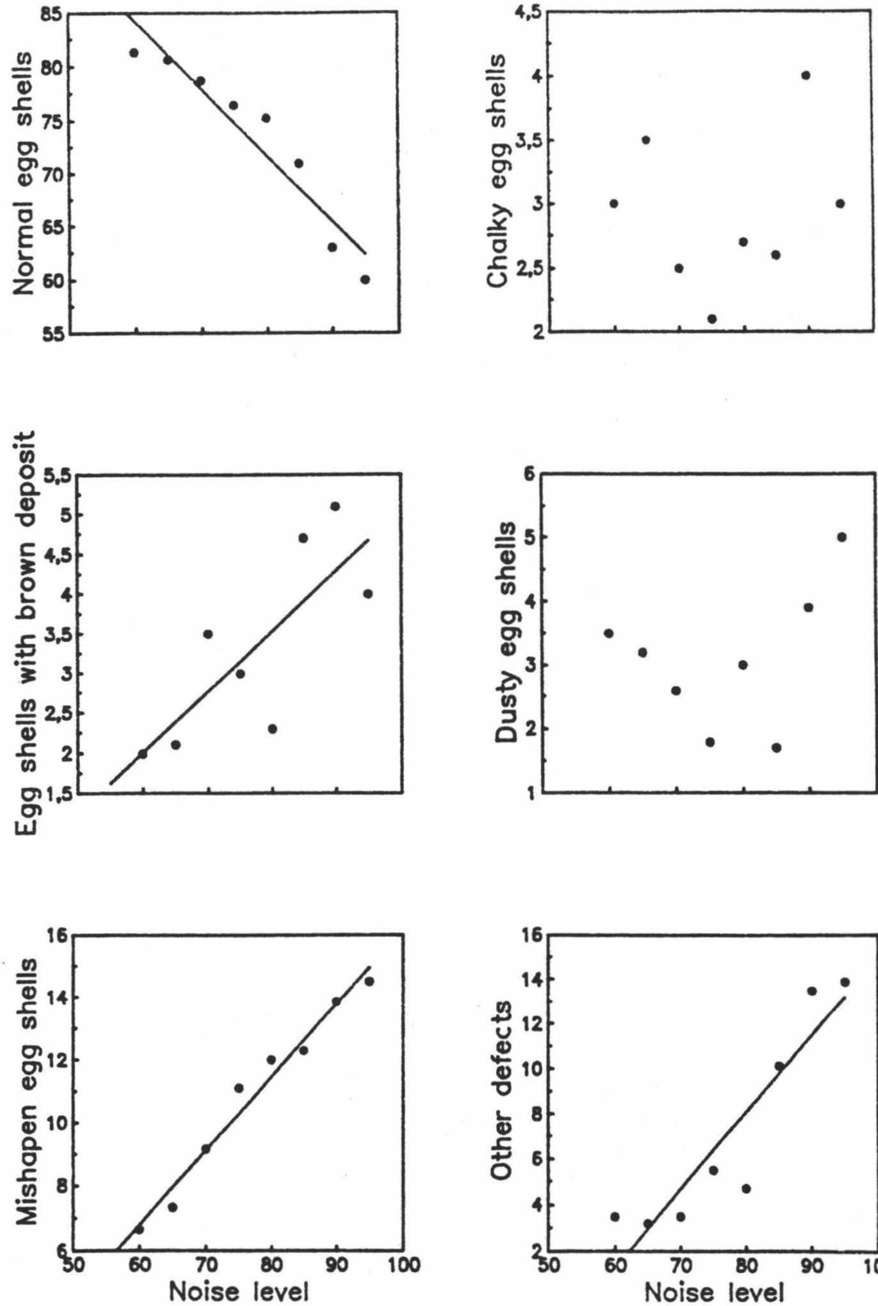

Figure 3.11. : Relationship between highway noise and normal, abnormal egg shells (%), produced by 200 hens exposed to different noise level (60 - 95 dB)

3.2. LAYING HENS UNDER FEEDER LENGTH STRESS

3.2.1. Introduction

Battery cages for laying hens are widely used in the commercial production of laying eggs. The reasons for this widespread acceptance are the lower labour costs per cage, easier visual inspection of the hens, better feed conversion and the high production efficiency due to high bird density.

One current management tool is to increase the number of hens per cage, resulting in a concomitant decrease of the feeder length available per hen. It is commonly believed that the increased number of hens per cage will increase egg production per cage, thereby contributing to increasing profitability.

However, as pointed out by BELL and SWANSON (1975), profits are not always enhanced when layer cages are overcrowded.

ROBINSON (1979) reported crowding hens involves three specific aspects : increased colony size, decreased floor area and decreased feeder space. The same author considers shortage of feeder space per bird as the most important causative factor for performance differences. Several researches have noted that a feeder length of 10 cm per hen would be sufficient for production and economic purposes - i.e. without taking into account the well-being of laying hens. An availability of 10 cm of feed trough was also recommended by the EEC directive of March 1986.

The present author wishes to stress (a) that more information and experience are required before final conclusions regarding optimal feeder length per hen can be drawn and (b) that it is absolutely essential to undertake further research on the issue of the most appropriate feeder length with regard to the welfare of the laying hens.

This section reports on experiments carried out in view of the determination of the effect of feeder length upon

- selected behavioural patterns,
- production indices in laying hens,
- egg quality,
- feather condition, and
- corticosterone levels in the hen's plasma;

the feeder length will also be analyzed in the context of the general well-being of laying hens and with regard to economic characteristics of the egg production process.

3.2.2. Behaviour

Table 3.16 gives the results of the analyses of variance of the various comfort behaviours as recorded for hens provided with different feeder lengths.

Counts per hour of standing, sitting, wing/leg stretching, body shaking and preening were significantly ($p < 0.01$) higher for hens housed in cages with 12.5 cm feeder length per hen as compared to the other cages. However, head shaking incidence was greater in type IV-cages with 13.3 cm/hen feeder length. Hens in cages with 10 cm/hen feeder length appeared to display less comfort behaviour activity; the difference with the other cages was significant ($p < 0.01$). The results also demonstrated that hens in cages with both 12 and 12.5 cm/hen feeder length displayed more comfort behaviour than those in cages with 13.3 cm/hen feeder length. The video tape recordings of individual cages are illustrated in figure 3.12.

Activity counts indicated that the standing trait was the most frequently observed type of behaviour, whereas body shaking was characterized by the smallest frequency of all behaviour traits. Wing flapping or attempted wing flapping was very seldom observed at all in any of the cages.

Extension of the feeder length from 10 to 13.3 cm had an important effect on feeding behaviour. Hens housed in type III and type II-cages (a) spent more time feeding, with at the same time more hens feeding together and (b) displayed a greater number of bouts than those in type I and type IV-cages. The feeding activities of the hens in type II-cages seemed to occur a little more frequent if compared to the hens in type III-cages, although this difference was not significant. Particularly short feeding times were observed for the group in type I-cages. The analysis of variance of the results revealed significant differences in the feeding activities (table 3.17).

There was also a significant effect of the time of day on the feeding behaviour. The results indicated that, in all treatments, less time was spent feeding at 18.00 h than at any other hour. Analysis of five observation times corroborated that bouts were more frequent at 12.00 hour than at other observation hours. Hens in type II, III and IV-cages had higher bouts frequency than hens housed in type IV and type I-cages, except for the frequency measured at 18.00 h. Nearly all the differences among the hours were significant between the treatments.

Little time was spent drinking by comparison with feeding activity. Hens in type II and type III-cages did more drinking compared to the hens in type I-cages (table 3.18). Like feeding behaviour, drinking activity was affected by the time of day.

Table 3.16 : Means and analysis of variance for comfort behaviour at different feeder length

Activities counts/hour	Feeder length types I-cage 10 cm/hen	II-cage 12 cm/hen	III-cage 12.5 cm/hen	IV-cage 13.3 cm/hen	MS	F	
Standing	7.00 *b*	13.56 *ca*	15.00 *a*	12.63 *dc*	60.7365	41.093	**
Sitting	4.00 *b*	8.86 *c*	11.04 *a*	10.75 *da*	53.0258	36.577	**
Wing/leg stretching	1.20 *b*	3.46 *c*	4.45 *a*	3.31 *dc*	9.3332	71.754	**
Head shaking	5.75 *b*	10.37 *dc*	9.44 *d*	11.76 *a*	33.0326	38.214	**
Body shaking	1.59 *b*	3.81 *c*	3.96 *ac*	2.14 *da*	7.0462	20.041	*
Preening	6.38 *b*	10.58 *dc*	12.77 *a*	9.48 *d*	35.3570	25.439	**

Means followed by different italic letters are statistically different with significance level $p < 0.05$
** $p < 0.01$
* $p < 0.5$

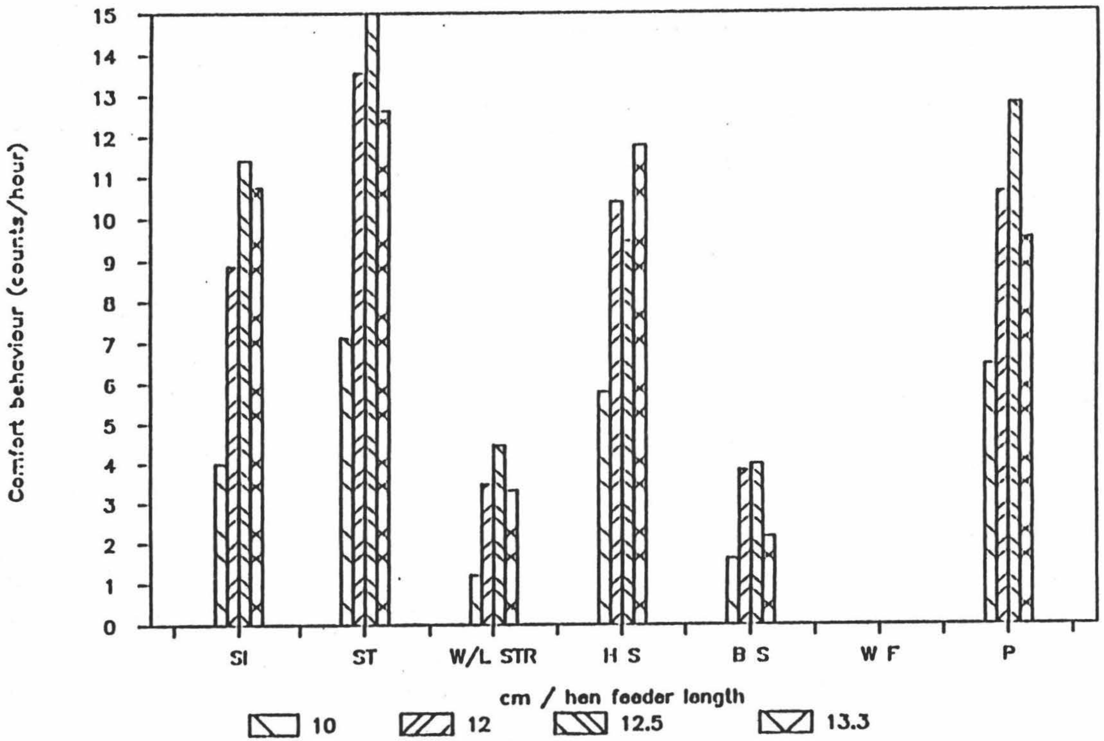

Figure 3.12 : Mean number of observations of the comfort behaviour of four groups of layers (n = 30) under different feeder length
Sit, stand, wing/leg stretch, head shake, body shake, wing flap, preen

Table 3.17 : Means and analysis of variance for feeding behaviour (counts in seconds, number of bouts and hen feeding together) at different feeder length (n = 30)

Observation hour	Parameters	Feeder length types: I-cage 10 cm/hen	II-cage 12 cm/hen	III-cage 12.5 cm/hen	IV-cage 13.3 cm/hen	MS	F	
8	Bouts no.	14.10 *b*	25.60 *a*	24.70 *c*	20.60 *da*	135.364	4.942	*
	Time spent	849.00 *b*	1 033.00 *c*	1 106.00 *a*	909.00 *d*	68 227.36	77.716	**
	Feeding together	2.50 *b*	3.30 *a*	3.70 *a*	2.80 *bc*	1.3599	3.729	*
10	Bouts no.	12.80	17.90	16.40	16.80	23.768	0.834	N
	Time spent	562.00 *b*	733.00 *a*	629.00	691.00 *da*	27 796.21	21.375	**
	Feeding together	2.20 *b*	3.10 *a*	3.50 *a*	2.20 *bc*	2.15	3.496	*
12	Bouts no.	20.90 *b*	30.60 *c*	28.40 *dc*	41.40 *a*	355.5111	12.803	**
	Time spent	1 172.00	1 331.00	1 448.00	1 302.00	64 233.03	3.021	N
	Feeding together	2.50 *b*	3.00 *c*	3.90 *a*	2.50 *db*	2.85	6.162	**
14	Bouts no.	15.90	18.10	18.10	15.00	15.9779	2.884	N
	Time spent	1 041.00 *bc*	1 078.00 *c*	1 306.00 *d*	1 390.00 *a*	142 930.44	47.298	**
	Feeding together	2.70	2.90	3.20	1.90	1.5458	1.571	N
18	Bouts no.	10.90 *a*	8.40 *c*	7.20 *bc*	6.30 *db*	19.623	4.112	*
	Time spent	766.00 *a*	478.00 *b*	623.00 *c*	444.00 *d*	108 793.61	324.081	**
	Feeding together	2.60	2.00	2.50	1.20	2.1553	1.446	N

Means followed by different italic letters are statistically different with significance level $p < 0.05$
N non significant (** $p < 0.01$; * $p < 0.05$)

Table 3.18 : Means and standard error of the number of pecks at water nipples and time spent (in seconds) per hour for hens under feeder length stress at five different periods of the day of observation hours (n = 30)

Observation hour	Parameters	Feeder length types			
		10 cm/hen	12 cm/hen	12.5 cm/hen	13.3 cm/hen
8	no. of pecks	3.6 ± 0.52	8.5 ± 0.43	7.7 ± 0.4	4.5 ± 0.4
	time spent	151.9 ± 3.5	161.9 ± 6.7	165 ± 4.8	171 ± 5.6
10	no. of pecks	3.5 ± 0.35	4.7 ± 0.57	5.0 ± 0.3	5.5 ± 0.38
	time spent	134 ± 3.9	147.2 ± 2.5	144 ± 3.9	135 ± 3.5
12	no. of pecks	4.9 ± 0.6	8.4 ± 0.65	7.5 ± 0.45	6.38 ± 0.3
	time spent	129 ± 3.2	242 ± 6.3	193 ± 4.2	187 ± 1.7
14	no. of pecks	2.9 ± 0.24	3.4 ± 0.4	2.3 ± 0.2	2 ± 0.19
	time spent	121.3 ± 4.2	159 ± 2.8	139 ± 2.5	171 ± 5.6
18	no. of pecks	2.8 ± 0.3	1.6± 0.45	1.3 ± 0.1	1.29.4 ± 1.9
	time spent	88 ± 2.4	61.4 ± 2.6	75.4 ± 3.9	53.4 ± 2.2

Feeder length had a strong effect on agonistic behaviour. The results indicated that a rapid increase in cage pecking was initiated by reducing the feeder length. The cage pecking performance of hens housed in type I-cages (with 10 cm/hen feeder) was higher than in any other cage type (figure 3.13).

Furthermore, there was a distinct correlation between feeder length and feather pecking. More feather pecking seemed to prevail among hens caged in type I-cages with 10 cm/hen feeder length. On the whole, hens in type III-cages displayed less agonistic activities than those housed in all other cages, the differences being significant ($p < 0.01$). Only with regard to agonistic pushing behaviour, incidence frequency in type III-cages was a little higher than in type II-cages (feeder length : 12 cm/hen). Results indicated that the pushing frequency increased during feeding times.

An interesting observation in this study was that hens housed in type IV-cages, which are characterized by the longest feeder length (13.3 cm/hen), showed a higher level of agonistic behaviour than those housed in type III-cages. It can be seen that the behaviour of the hens housed in type IV-cages was intermediate. Significant differences between treatments were again found. The pertaining results are shown in figure 3.13. The analysis of variance is summarized in table 3.19.

3.2.3. Production performance

A detailed account of the effect of feeder length on the egg production is summarized in table 3.20. Feeder length significantly ($p < 0.05$) affected egg production. Increasing the feeder length per hen from 10 to 12.5 cm raised production by 4.5 %. Hens caged in type III-cages had the highest egg production rate. A feeder length of 12 cm/hen (type II-cage) corresponded with a significantly ($p < 0.05$) higher egg production than in the case of a feeder length of 10 cm/hen. The egg production percentage increased from 73.8 % in the cages with 10 cm/hen feeder length to as high as 78.66 % in the cages with feeder length 12 cm/hen. However, the differences between the cages with 13.3 cm/hen feeder length and those with 10 cm/hen were not significant. The data distinctly show that the egg production level improved by raising the feeder length up to 12.5 cm/hen.

Measurements revealed that egg mass was directly related with the length of the feeder. Hens in the type III-cage (12 cm/hen) cage produced eggs with an average mass of 47.27 g, which was heavier than those laid by hens housed in type I and IV-cages, these differences being significant. However, the difference between type III and II-cages was not significant.

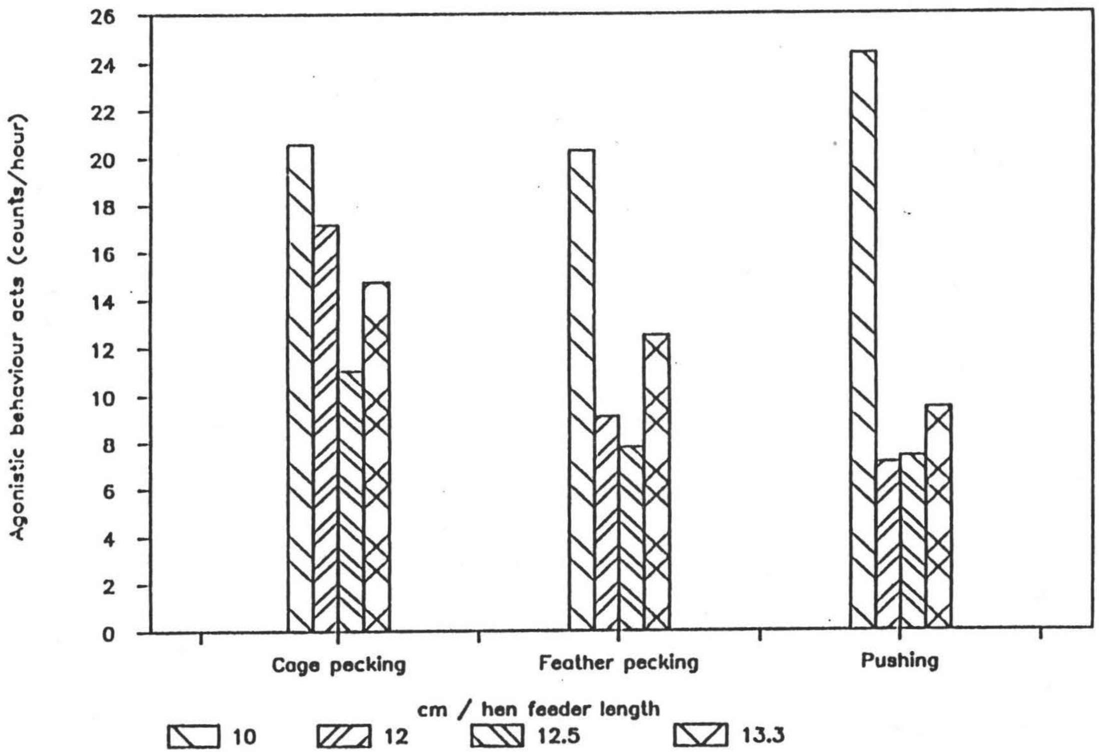

Figure 3.13 : Effect of feeder length on agonistic behaviour counts per hour and results represented as means

Table 3.19 : Effect of feeder length stress on the agonistic behaviour counts per hour per hen. Results represented as means (n=30)

Agonistic behaviour counts/hour	Feeder length types: I-cage 10 cm/hen	II-cage 12 cm/hen	III-cage 12.5 cm/hen	IV-cage 13.3 cm/hen	MS	F	
Cage pecking	20.58 *a*	17.17 *a*	11.03 *b*	14.75 *c*	80.848	6.355	**
Feather pecking	20.30 *a*	9.08 *b*	7.70 *c*	12.50 *b*	157.853	15.914	**
Pushing	24.36 *a*	7.11 *b*	7.37 *c*	9.46 *d*	341.223	30.114	**

Means followed by different italic letters are statistically different with significance level $p < 0.05$
** $p < 0.01$

Table 3.20 : Means and analysis of variance of production performance of hens housed in cages with different feeder length

Parameters	Feeder length types: I-cage 10 cm/hen	II-cage 12 cm/hen	III-cage 12.5 cm/hen	IV-cage 13.3 cm/hen	MS	F	
Egg production (%)	73.81^{bc}	78.66^{da}	80.34^{a}	75.08^{dc}	17.2647	4.231	*
Egg mass (g/hen/day)	43.27^{db}	45.05^{ad}	47.27^{a}	44.24^{dc}	11.6154	5.444	*
Feed intake (g)	111.08	112.96	113.83	114.30	8.079	0.914	N
Feed conversion	2.64^{da}	2.33^{b}	2.45^{dc}	2.71^{a}	0.1212	5.413	*
Body weight (g)	2 100	2 193	2 190	2 210	16 641.33	0.264	N
Gain weight (g)	188.4^{bc}	235.4^{a}	224.7^{ad}	210.5^{ac}	1 651.209	5.750	*
Dirty and broken eggs (%)	7.46^{a}	2.81^{b}	2.34^{bc}	5.86^{da}	34.0129	5.928	*
Mortality (%)	8^{a}	3^{bc}	2^{c}	7da	3.396	5.391	*

Means (n = 30) followed by different italic letters are statistically different with significance level $p < 0.05$

* $p < 0.05$ N non significant

Feeder length also affected feed intake. The hens in type IV-cages, with 13.3 cm feeder length per hen, consumed more feed than hens in type III, II and I cages.

Feed conversion was found to be strongly influenced by feeder length too. Increasing the feeder length from 10 to 13.3 cm/hen resulted in heavier body weights for hens in type IV and type II-cages (table 3.20). In the type II and type III-cages, the 12 and 12.5 cm/hen treatments resulted in hens weighing respectively 235.4 and 224.7 g heavier than those at the beginning of the experiment. The differences were significant ($p < 0.05$) both between type II and type I-cages and between type III and type I-cages.

The feeder length had a significant effect on the percentage of dirty and broken eggs. Type II and type III-cages lost fewer eggs than type I and type IV-cages. Feeder lengths of 12 and 12.5 cm/hen decreased the percentage of dirty and broken eggs to 4.65 and 4.12 % respectively.

There was also a significant difference in mortality between the various cages. A clear trend for less dead hens was found in the type III-cages, the difference being significant when compared with the type I and IV-cages. However, the difference was not significant between the cages of types II and III.

3.2.3.1. Egg quality

The results of egg weight versus feeder length are presented in table 3.21. Hens caged in type II, III and IV-cages laid significantly ($p < 0.05$) heavier eggs, produced more egg mass, and had a higher percentage of eggs above 70 g than hens in type I-cages with 10 cm/hen feeder length. Shell weight and percentage were affected by feeder length as well; however, the differences were not significant. Shell deformations were found not to be influenced by feeder length.

Increasing the feeder length from 10 cm to 12.5 cm/hen decreased the incidence of meat and blood spots, the differences being significant ($p < 0.01$). However, there was no significant difference in frequency of meat and blood spots between hens housed in the cages of type IV - with 13.3 cm feeder length per hen - and hens in type I-cages with a feeder length of 10 cm/hen.

Table 3.21 : Means for egg quality and analysis of variance between different feeder length (n = 120)

Parameters	I-cage 10 cm/hen	II-cage 12 cm/hen	III-cage 12.5 cm/hen	IV-cage 13.3 cm/hen	MS	F	
	Feeder length types						
Egg weight (g)	61.26 *b*	64.40 *ca*	65.88 *a*	62.27 *da*	16.555	2.134	*
Shell deformation (1 000 x mm)	16.05	15.56	15.62	17.41	2.331	1.592	N
Shell thickness (mm)	0.351	0.352	0.345	0.341	6.168	0.208	N
Shell weight (g)	4.62	6.16	6.22	5.27	1.777	1.658	N
Shell (%)	7.53	9.45	9.20	8.32	6.678	0.606	N
Meat and blood spots (%)	9.81 *a*	4.82 *c*	4.25 *b*	8.91 *da*	0.117	12.549	**

Means followed by different italic letters are statistically different with significance level $p < 0.05$

** $p < 0.01$

N non significant

3.2.3.2. Feather condition

Scoring results relating to the various body parts are summarized in table 3.22. Feeder length distinctly affected feather condition. Figure 3.14 shows the evaluation by means of both scoring methods and the average of the hens' exterior appearance in all treatments. At this occasion there was significant ($p < 0.01$) difference in points for all body parts. The plumage of the hens in cages with 10 cm/hen feeder length was consistently worse compared with all other treatments. This fact corresponds with the observation that the total sum of 'feather points' for the whole body was usually significantly lower for the hens housed in type I-cages (with 10 cm/hen) when compared with the hens housed in cages of types II and III.

Arranging the various body parts according to the level of deterioration of local feathering leads to following order: breast > back > wing > neck > tail (cage type I, plate 3.5). It was generally observed that the most affected part of the body for all the treatments was the breast (plate 3.6), for which there was a significant difference in feather condition between the cages. Hens in cages of types II and III (feeder length : 12 and 12.5 cm/hen respectively) were characterized by a lower level of plumage deterioration as compared with hens in the other cage types.

A significant difference was found between cage types II, III and I when the average points of whole body and single scoring were considered.

3.2.3.3. Corticosterone levels in the hens' plasma

Mean plasma corticosterone concentrations from hens sampled throughout the duration of the experiments are depicted in figure 3.15. The results showed that hens in type II and III-cages have low plasma corticosterone levels, i.e. 22.76 % and 23.51 % corresponding with 12 and 12.5 cm/hen feeder length respectively. These values are less than those for hens housed in type I-cages (with 10 cm/hen). Thus, for the above three cage types a decrease in level of corticosterone with increasing feeder length was registered. However, this phenomenon did not occur in hens caged in type IV-cages (13.3 cm/hen feeder length), where the corticosterone level was higher than in hens housed in type I-cages - this difference however not being significant. Results also revealed that increasing the feeder length from 12.5 to 13.3 cm/hen caused a rise of 5.96 % in plasma concentrations of adrenal steroids.

Table 3.22 : Means and analysis of variance for condition of plumage of five body parts of hens housed in different cages (n = 90)

Parameters	Feeder length types I-cage 10 cm/hen	 II-cage 12 cm/hen	 III-cage 12.5 cm/hen	 IV-cage 13.3 cm/hen	MS	F	
Neck	2.17 *c*	2.99 *b*	3.75 *a*	2.08 *dc*	11.942	3.0926	**
Breast	1.87 *c*	2.80 *a*	3.45 *a*	1.79 *bc*	12.934	3.1511	**
Back	1.95 *d*	2.84 *b*	3.55 *a*	2.11 *dc*	18.739	2.7132	**
Wing	1.92 *b*	3.05 *a*	3.60 *a*	2.60 *c*	14.185	2.5149	**
Tail	2.25 *c*	2.80 *d*	3.70 *a*	2.20 *bc*	14.699	2.4160	**
Total	10.18 *bc*	14.50 *bc*	18.06 *a*	10.78 *c*	20.355	6.9067	**
Single	9.90 *d*	13.70 *bc*	19.15 *a*	11.90 *c*	24.649	7.0075	**
Average	10.04 *b*	14.10 *d*	18.69 *a*	11.34 *bc*	25.995	7.6811	**

Means (n = 120) followed by different italic letters are statistically different with significance level $p < 0.05$
** $p < 0.01$

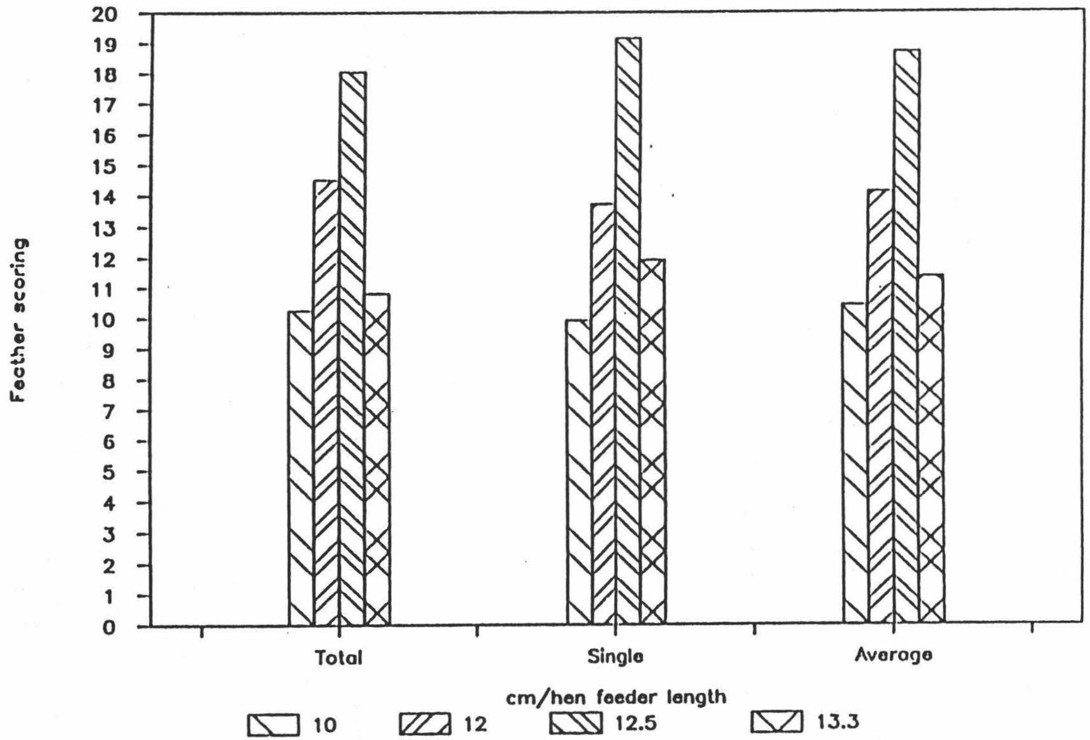

Figure 3.14 : Effect of differences of feeder length on the plumage condition and results presented as means (n = 120)

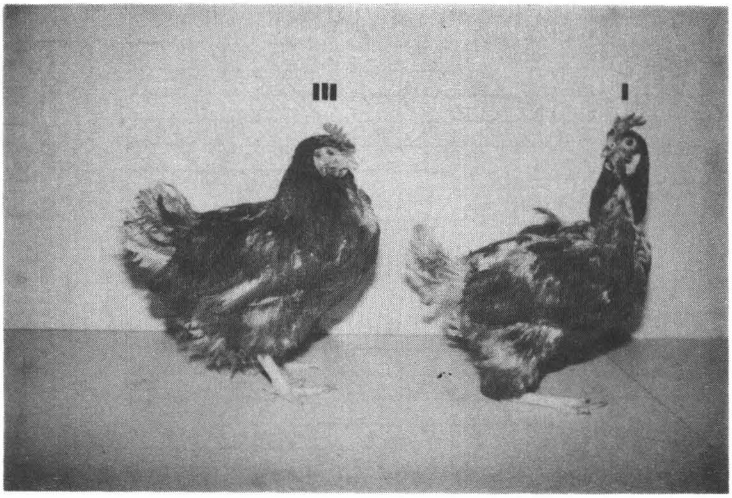

Plate 3.5 : Comparison between tail feathering of two hens housed III and I-cages

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2.

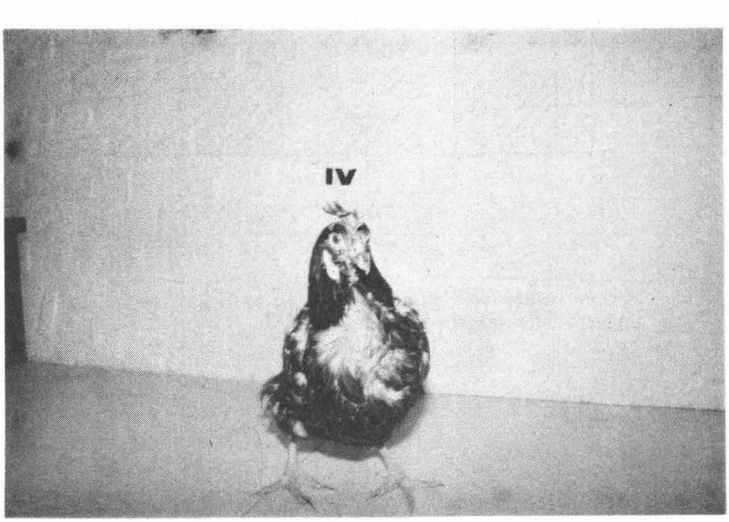

Plate 3.6 : Difference in breast feather condition between hens caged in III and IV-cages

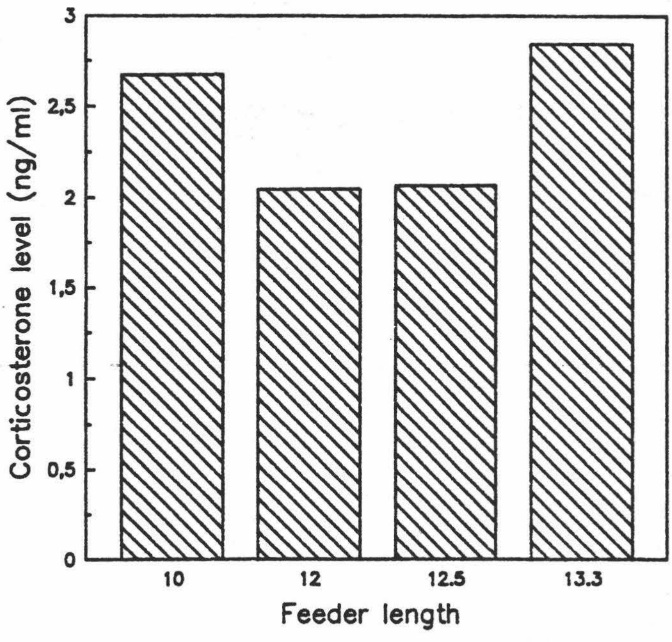

Figure 3.15. : Means values of corticosterone concentration measured in hens under feeder length stress (n = 30)

3.2.3.4. Economy

In table 3.23 profits per cage are compared between the treatments; all results in the table refer to the formula:

cage profits = gross returns/cage - total costs/cage

Feed cost and total egg loss were found to be responsible for either the increase or the decrease of the net egg income. Cage type II resulted in an egg income which was respectively 6.69 and 7.34 BF/cage higher than the corresponding value for the type I and III-cages. The lowest income was recorded for the cages with 13.3 cm/hen, which had the highest cost per cage.

Table 3.23 : Cage profits (BF) for the treatment under various feeder length stress

Cages	Gross returns/cage (BF)	Total costs/cage (BF)	Cage profits (BF)
I	3 426.610	3 377.575	49.035
II	3 466.150	3 410.425	55.725
III	2 910.856	2 861.480	48.376
IV	2 035.578	2 001.585	33.993

4. DISCUSSION

4.1. INFLUENCE OF NOISE STRESS ON LAYING HENS

4.1.1. Production performance

On poultry farms various kinds of machinery are used. It is evident that these usually electrically powered appliances (e.g. feeding machines) produce noise. This noise is known to have an unfavourable effect on the production of eggs (KAWAHARA, 1976 and KAZUSHI and SUGAWARA, 1986) although research in this area has been scanty. Therefore, there is a need for further research in this field.

The present study revealed that production record very distinctly indicated that egg production was seriously reduced by highway noise. Whereas a certain difference between the control group and the group subjected to feeding machine noise was registered, this difference was not statistically significant. The feeding machine influenced egg production only in the earlier part of the laying period. At a more advanced stage, the effect was not pronounced. The control group featured a greater egg production, which was mainly due to a lower mortality and a lower frequency of undergrade eggs, including dirty and broken eggs.

The above results are in agreement with those published by IVOS et al. (1976) and KAZUSHI and SUGAWARA (1986). The former authors found that the average rate of egg laying was lower in groups exposed to noise than in the control groups, with a maximum difference of 20 %. The same research workers concluded that the egg production was negatively correlated with the noise level to which the animals were subjected. Combining our own results and those from investigations conducted at other institutes, it was concluded that noise levels of 75 dB and higher may damage egg production. Providing the feeding machine with proper housing is a rule which has to be observed strictly in order to reduce the noise level inside the poultry house. A reduction of 6 dB in noise level corresponded with an egg production increase of 2 - 5 % as well as a 2 % decrease of dirty and broken eggs.

Differences in laying house mortality were significant between the treatments. Higher mortality percentages were observed for the group loaded with highway noise as compared with the control group. These results are generally consistent with the findings of IVOS et al. (1976), who found that mortality reached 23.1 % in a group treated with noise against 17 % in the control group. The present study indicates that the feeding machine noise caused an increase of mortality with 11.6 %. Consequently, the higher mortality rate reduces egg production.

Interesting results contained in the present study were (a) that most of the deaths in the group treated with feeding machine noise occurred in healthy hens and (b) that there was a general and marked peak in the rate of mortality between 20 and 30 weeks of age (this corresponds with the period necessary for adaptation to the noise). Regarding the latter aspect, it should be noted that here were no obvious diseases caused by viruses or bacteria. Therefore, our results can be considered similar to the findings of EWBAND and MANSBRIDGE (1977) who stated that loud noise can result in death or damage to hens. Thus, the final conclusion is that noise must be considered hazardous for the hens' health. The frequency of sudden death ranged between 20 - 30 % of total mortality. However, today such outbreaks of death also occur in commercial flocks, and sometimes - when the feeding machine was very old causing an unacceptable noise level - to even more serious extents. It is possible to successfully reduce the frequency of sudden death by oiling the feeding installation at least 3 times a year.

Another kind of mortality, i.e. due to cannibalism and accidents, was observed. The group treated with noise displayed an alarming tendency to escape through the bars of the cage, an activity causing injuries which may eventually lead to the hens' death. Sudden noise becomes an even greater predicament when the hens first become frightened and then try to escape, this reaction almost certainly having an important death toll. Excessive noise, such as highway noise or sudden noise of the feeding machine, can thus trigger the phenomenon of sudden death. This means that an increased mortality rate can be an indicator of the quality of management and may be the subject of legal considerations regarding animal welfare.

Examination of the feeding activity data obtained in this study suggested that both feed conversion and feed intake per hen per day were affected by noise. Hens subjected to noise consumed more food than the control group and had lower egg mass, resulting in less favourable feed conversion figures. This extra food intake is an immediate loss for the egg producers. The high feed consumption in the group subjected to noise could be explained by the heavy feather pecking resulting in very bad plumage and consequently also in greater maintenance requirements of the hen, the latter being largely dependent upon the animals' feathering condition. A positive correlation between feather deterioration related and feed intake was indeed observed.

The final body weight was significantly affected by noise stress, although the high feed intake recorded for the group of hens treated with highway noise was not enough to increase their body weight. These results do not correspond with the findings of BOND et al. (1963), who found no change in rate of growth, feed intake or feed consumption efficiency in swine subject to loud aircraft sounds. The present investigator explains this non-similarity by the use of different species.

Another reason for the lower overall egg production in the group treated with noise was the increased percentage of undergrade eggs. The frequency of undergrade eggs was strongly correlated with the noise level. The increased incidence of undergrade eggs laid by hens in the group exposed to the feeding machine noise resulted mainly from a higher incidence of broken and dirty eggs. It is interesting to note that in the above treatment most of the broken eggs were caused by the hens dropping the eggs before they found a suitable place for laying. This was particularly so at the beginning of the feeding period when the feeding machine was operated thus producing a sudden noise. The results showed that this sudden noise raised the frequency of broken and dirty eggs by 4.48 %. The incidence of broken eggs which is recorded today in commercial egg production has been estimated from 6 to as high as 11 % of all eggs produced. The latter value is based on the 6 - 7 % value for the United Kingdom (ANDERSON and CARTER, 1976), and 7 % for Belgium. These percentages probably underestimate the actual damage, as it is obviously difficult to detect all the losses.

Observations indicated that hens in the group loaded with highway noise displayed egg eating. Once hens start this habit, identifying the culprits can be very time-consuming, while at the same time they can soon spread their habit to others. Indeed, experienced egg eaters will eat their own eggs. The problem is usually initiated by the hen finding a broken egg, pecking at it out of curiosity, and next starting to eat it. It is often suggested that the habit arises because of some nutritional deficiency. The present author assumes following explanation. Noise stress is guaranteed to cause panic, nervousness or sometimes hysteria. In that case hens lose control resulting in a lot of abnormal behaviour, one of the activities being egg eating.

All by all, egg eating was yet another reason reducing egg production in the group treated with noise. The suggestion was made to solve the problem by reducing the noise level in poultry house to a value below 55 dB. However, this solution will no doubt lead to considerable economic losses for the poultry industry. Therefore, it is again best to pay attention to the actual amount of noise produced by feeding machine.

Eventually, the influence of either sudden or excessive noise resulted in an increase in undergrade eggs. The principal causes were nervousness, sudden jumps or dropping ; it was furthermore observed that the nervous hens could eat almost the entire egg before it drops through the cage. Administration of adrenaline has been shown to inhibit egg production as will any stressful situations. All the production parameters suggested that the highway and feeding machine noise affected the laying hens and depressed their welfare.

4.1.2. Egg quality

Egg shell quality has been a subject of major concern for more than 60 years, and interest appears to be increasing as the magnitude of the problem of weak, broken or abnormal egg shells is readily recognized in commercial egg production.

Many factors are associated with egg quality, such as age of hens (BROOKS, 1971), temperature and humidity inside the laying house (ANONYMOUS, 1972), and the design of the cage system (BEZPA et al., 1972). The environmental conditions of livestock have changed in various respects during the last two decades. The increased mechanization inside the poultry house has resulted in ever greater noise disturbances to the hens.

This study was generally designed to determine whether there was a direct effect of this environmental factor (noise) on the egg quality.

The results indicate that noise of a highway clearly affected egg weight, shell deformation, shell thickness, shell weight as well as the percentage and frequency of blood and meat spots. The latter characteristic was the only one also affected by the noise produced by the feeding machine. The experimental results reported in this study confirm those of STILES and DAWSON (1960), who found that eggs from hens subjected to abnormal sounds had increased blood spot incidence. In contrast, no significant effect of the sounds was observed on the frequency of occurrence of blood spotted eggs (SEIKAN et al., 1963). The difference in blood and meat spots incidence was 8.4 and 16.19 % higher for the groups loaded with noise of the feeding machine and the highway respectively. The reason for the higher blood and meat spots incidence probably is that noise affected the time of secretion by the pituitary of both the luteinizing hormone (L.H.), which influences ovulation time, and the follicle stimulating hormone (F.S.H.), which is determinant for the ovum size. A relationship between ovulation time, egg weight, and blood spot incidence was shown to exist in an earlier publication (STILES, 1958). Since noise was proved to cause frustration to the hens, L.H. secretion may thus be inhibited.

The findings with regard to egg shell deformation show that highway noise also has an effect on the deformation of the egg shell. A possible explanation for this is that the noise stress, induces the release of adrenaline, which (a) produces shell gland contraction at a critical period (about 5 hours after ovulation) when calcification of the shell is well advanced and (b) also causes stretching of the membranes making the thin shell crack and therefore deform.

Highway noise had significantly affected shell thickness. STILES and DAWSON (1961) reported that frightened birds produced eggs with significantly decreased egg shell thickness. EL-BOUSHY et al. (1968) reported that under climatic stress, the thickness of the whole shell and its layers is significantly diminished.

It was found that both shell weight and percentage had been affected by the highway noise. Highest shell weight corresponded with greatest shell thickness and vice versa.

Eggs from hens exposed to feeding machine noise had increased blood and meat spots, but none of the other quality characteristics were affected. Although there is no doubt that both noise of the highway and of the feeding machine had clearly affect the egg quality, the present investigator suggests that more research is needed on these aspects.

4.1.3. Behaviour

4.1.3.1. Comfort behaviour

In order to assess welfare among hens under different housing environmental conditions, several behaviour studies have been carried out (HUGHES, 1973).

Most often, a change in the environment of an animal will eventually result in changes in behavioural repertoire. Noise, one of the environmental factors, has become an increasingly big environmental problem. This problem has not been given much attention.

The aim of this experiment is to facilitate the understanding of the influence of excessive and sudden noise on the comfort behaviour of laying hens.

In these behaviour patterns, there were clear differences between hens housed in the control group and those in the groups treated with noise. The differences may confidently be ascribed to the excessive and sudden noise.

The crucial question is : are the hens responding differentially or does the altered behaviour represent adaptation or novelty acts to the noise which imposes a degree of stress ? The differences between the groups are indeed non-consistent since the noise actually provided different stimuli or variation among hens resistant against noise stress, and thus led to reduced or altered comfort behaviour.

The highway noise had markedly affected the hens comfort behaviour. Most of the hens in the group looked very weak and sick, and the mortality rate was high. The only possible explanation was a gradual decline in the hens' immunity or natural defence system due to noise stress. According to ALGERS et al. (1978), inoculated mice were more resistant than non-inoculated mice after exposure to noise. Unfortunately, this factor was not measured in the present study.

Feature reactions to highway noise were observed in the experiments. These particular reactions can be described as startle response, nervousness, aggressiveness, moving a lot or jerkiness. In the case of feeding machine noise, the first period of noise exposure disturbed the hens more than subsequent exposures. This may be characterized as a fright reaction. Excessive noise caused some of the hens to break or eat their eggs, or (c) to try to escape through the door of the cage, (b) to panic and become nervous. Once the hens had learned with time that they could not escape, comfort behaviour depression and activation of the pituitary adrenal axis resulted.

Sitting behaviour was the most common expression of resting behaviour. Obviously, sitting is a very stable position, the more so as poultry possess a mechanism by which - when the animals sit - the feet are drawn close to their body, on the floor of the cage. During the day, resting was mainly present as dozy standing, which was obviously the most alert resting posture. The deeper resting states were mainly shown during the last hours of the light period. The control group spent more time for sitting than the other groups.

Resting showed a very strong rhythmic organization (BLOKHUIS, 1984), indicating that there may be some other (external) factors involved as well, as suggested by WOOD-GUSH (1971). Such factors may lie, for instance, in the relationship with other behavioural patterns or in the functional significance of resting itself. The present observational study points to noise being another suchlike external factor influencing resting behaviour (sitting and standing). Noise of the highway and the feeding machine regularly interrupted the resting behaviour by increasing other behavioural patterns.

Preening and wing/leg stretching behaviour were exhibited several peaks in the early morning and one at mid-day; the hens' performance was similar to that previously recorded for preening (WOOD-GUSH, 1959, BESSEI, 1977). The former author suggested that the diurnal rhythm of preening may be associated with a rise in the relative strength of tactile stimuli after other, more urgent, behaviour has been completed. Indeed, our own data clearly suggested that feeding machine and highway noise can alter the performance of the laying hens.

In conclusion, our findings demonstrated that the decline in the comfort behaviour resulted in stress caused by noise of the feeding machine and highway. When assessing noise stress or the suitability of management environments, it is important to take into account all forms of behaviour. The hens' well-being is a state characterized by the disappearance of suffering from stress, just as health is a state characterized by the absence of disease. Obviously, an exact diagnosis of either condition cannot be based on behavioural observations alone. The more numerous the symptoms which indicate the stress of the laying hens - particularly if coupled with physiological or morphological symptoms of illness and damage - the greater the validity of diagnosis of noise stress.

4.1.3.2. Maintenance behaviour

The findings indicated that noise stress had an outspoken effect on the feeding activity. The time spent feeding by the control group was appreciably more than by the other groups; this suggests that feeding activities of the hens in the noise loaded groups are performed under stress. However, these feeding activities (number of bouts, times spent and number hens feeding together) were not associated with the amount of food intake because the hens under noise stress ate more than those in the control group. The only acceptable explanations are (a) that during the exposure period, the hens under stress feed very fast with a lot of (unrecorded) waste food and (b) stressed hens had a typically poor feather condition.

Noise appears to affect the maximum number of hens feeding simultaneously. More hens were observed feeding together in the control group as these hens were calm and more relaxed during feeding time.

Furthermore, noise stress markedly affected the feeding rhythm. Immediately after the starting of the photoperiod, more hens were feeding in the control group than in the other groups. The highest frequency of bouts was also observed in the control group. Most of the hens were laying during the first hour of the morning ; the feeding activity consequently declined at about 10.00 h, increasing again at midday.

As the end of the photoperiod approached, there were again less hens feeding in the control group. Conversely, in the other groups the feeding rhythm was distinctly affected by noise : the noise induced stress formed a restriction for the hens which lost control and were unable to feed properly.

Drinking behaviour is closely related to the feeding behaviour ; thus it was to be expected that noise stress would affect the drinking activity too. Drinking activity was also subject to a diurnal rhythm, with one maximum at the beginning of the photoperiodic day and one at 12.00 h, leading to a minimum at the end of the light period. It was noticed that hens spent 5 to 6 % of the light period drinking, a value which corresponds well with the 4 - 6 % as reported by KIVIMAE (1976).

4.1.3.3. Hen position

Movement of the groups varied with the period of observation. During the morning, movements were more intense than in afternoon periods; hens are usually very active during the morning, with feeding behaviour in particular in the early morning. The results indicate that in the morning the hens in the control group spent more time in the front than in the back of the cage.

During both morning and afternoon, hens under highway noise stress were present more often in the rear half than in the front half of the cage. These hens showed a reduction in activity and sometimes were totally immobilized in the rear half of the cage. At the beginning of the exposure all the hens huddled in a group at the back of the cage ; some of them remained in this position for 3 - 4 minutes. After that they started moving again, but returned to the rear of the cage. It was observed that they all looked in the direction of the noise source.

The group loaded with feeding machine noise appeared either freezing into motionless stance or moving very fast between the rear and the front of the cage when the feeding machine noise is applied. They would remain in this frozen or moving position for a few seconds. After continued exposure to this phenomenon for a few weeks, the tendency of assuming a frozen position becomes much less. An interesting observation was that the fast movements undertaken by the hens during exposure times appeared to show no signs of adaptation or change. However, with the exception of this type of behaviour, the hens returned to normal or near-normal after adaptation.

During the morning, the hens in the group loaded with feeding machine noise spent more time in the front of the cage, the only explanation for this behaviour being the feeding activity.

Finally, it should be pointed out that whenever a hen wants to change its position, all the hens are disturbed.

4.1.3.4. Agonistic behaviour

The noise of the feeding machine and the highway increased the agonistic behaviour. Frequencies of agonistic behaviour for each group based on counts per hour were calculated. Usually, pecking occurred most in the stressed hens because noise caused nervousness and aggressiveness. The present author assumes that hens in the groups treated with noise tried to take off their nervousness and aggressiveness by pecking vigorously and at the cage in particular, as the cage structure is available for each hen in the group.

Feather pecking was also clearly induced in the group treated with noise; the weaker hens are made to duck and become victims. Hens in groups treated with noise displayed more feather pecking than those in the control group. This may be a result of noise stress, as most feather pecking occurred during the exposure period.

Feather pecking progressively causes plumage losses and, sometimes, skin damage. When the noise level increases, it may cause severe wounds and may precede killing behaviour. Noise increases agonistic behaviour and also influences the health of laying hens (ALGERS et al., 1978). The most interesting observation is that particular injuries occurred in hens in groups subjected to highway or feeding machine noise, including wing and comb damage.

The results showed that increasing noise levels result in a rise in cage, trough and feather pecking, while at the same time the hens group to create high noise levels (squawking). The laying hens' behaviour is affected by noise levels above 70 dB. Normally, noise ranges from 50 - 55 dB at normal times to 70 - 85 dB at feeding times.

Pushing agonistic movements occurred in groups treated with both feeding machine and highway noise. It was displayed when the closely confined hens execute a change in direction as a result of the sudden noise of the feeding machine.

Hens may suddenly start flying about and increase vocallization (squawking). This kind of behaviour is called hysteria. This phenomenon may last for a few seconds and even minutes in the groups treated with feeding machine and highway noise respectively. In addition, population pressure appears to be a helper cause of the build-up of hysteria in a noisy environment, leading to pain and suffering more easily. These activities obviously depress the welfare of the laying hens.

Eventually, in hens kept in the group exposed to the highway noise, the degree of novelty increased; on the other hand, comfort behaviour may become abbreviated as well as less frequent. Several researchers pointed out that reported differences in agonistic behaviour levels may be the result of factors such as strain differences, period of observation, group size, cage design and lighting programme (CUNNINGHAM and VAN TIENHOVEN, 1984). Another factor to add is the genetic difference among the hens to tolerate different levels of environmental stress. While no attempt was made to measure genetic characteristics in various strains, such studies may be desirable.

Our conclusion is that noise stress is another "causative factor" of agonistic behaviour.

4.1.3.5. Abnormal behaviour

The experimental data reflected an influence of noise stress on abnormal behaviour. Noise stress was clearly recognized by the typical abnormal behaviour reactions it produces in hens : jumping more than once (immediate flight), head and feather pecking as well as cannibalism (fight), trough pecking and pushing (nervousness) or avoidance and moving (escaping).

We noted that hens subject to feeding machine noise showed signs of agitation for a few seconds and then started pecking for a while, whereas those which had just been loaded with noise, although no further from the source of the disturbance, appeared to be relaxed and often began to feed. Feather or head pecking were more frequent in the group treated with noise produced by the feeding machine than in the control group. Various researchers suggested that causative factors for pecking activities could be bill-trimming, reduced light intensity (KULL, 1948), high stocking density (SIREN, 1963 ; TAUSON, 1985) and inadequate food conditions. Our results suggested that another factor which could lead to pecking is the feeding machine noise, especially when the machine is very old. Whether this increased pecking actually leads to damage will depend on the stimulation provided by the noise of the feeding machine.

Apparently, these findings are similar to HUGHES and DUNCAN's (1972) conclusions. In their study, these authors demonstrated that disturbed birds are more likely to begin feather pecking. In the present study after adaptation, some of them no longer paid attention to the feeding machine noise. This implies that there are variations among the hens for adapting to the feeding machine noise. The evidence for non-adaptation after the exposure to feeding machine noise, is that hens show physiological changes (an increased corticosterone concentration) suggestive of stress responses.

Video recordings made during the experiments showed that highway noise markedly caused increasing abnormal behaviour. It was observed that an unusual form of pecking behaviour, namely pecking at the cloacal region, was performed as a result of exposure to highway noise. The results point out that it can certainly be assumed that hens subject to highway noise were basically nervous and aggressive, these states leading to the high incidence of pecking.

It was found that serious pecking at the vent or comb and sometimes at the neck (relevant to hen welfare considerations) occurred more often in the noise loaded groups. Such pecking can lead to injuries and possibly to cannibalism. This problem may lead to serious damage when hens simultaneously regard a single hen as an attractive pecking object. Sometimes noise of the highway or even of the feeding machine also caused jumping and moving more than once. This particular behaviour could result in minor wounds on the wings or feet. This stimulates the attackers to attack the wounded hens. Consequently there is a greater probability that these minor injuries will result in death.

In conclusion it can be stated that whenever the noise of the highway and the feeding machine were exerted, they had an immediate effect on pecking and cannibalism.

Other possible "causative factors" are hormonal influence and social facilitation (HUGHES and DUNCAN, 1972). The latter researchers indicated that the endocrine balance of the bird may well be important, in view of the association between pecking or moving and the onset of lay in pullets. The evidence relating to psychic factors also seems to be largely qualitative. It was stated that trough pecking, moving or cannibalism develops in one or more individuals and from them spreads to other cage members and sometimes to the neighbouring cages. These results are similar to the findings of SIREN (1963).

Finally, the hens under noise stress are more likely to suffer from minor injuries caused by scratches, moving more than once or trying to escape through the cage sides.

4.1.4. Economy

The means calculated throughout the experiments show consistent, significant trends for several of the performance traits investigated. Most differences may be economically important to egg producers.

The commercial egg industry has to accept that 6 - 11 % of their production is lost through egg shell damage, dirty and broken eggs as well as through downgrading. These problems represent the basis for economic failure as encountered by egg producers. Several investigators have tried to solve the problem without giving attention neither to noise stress caused by the machinery used inside the farm nor to the noise level outside the farm.

In the present experiment, gross returns per cage was proved to be markedly affected by noise and especially by the highway noise. The group of hens subjected to highway noise was characterized by a much poorer gross return as compared to the control group, where the hens laid far more larger eggs with a higher survival rate. It is very interesting to note that the feeding machine noise resulted in the loss of 4.87 BF per cage, an amount which might well be of economic importance to the producers.

Poultry producers are loosing millions of franks per year as a result of cracked or broken eggs. Damaged-egg loss is frequently considered as part of the production cost, and, when kept at a minimum this may be acceptable. However, if damage starts to increase and the actual loss figure is never analysed, the cost to the producers may exceed what is considered as the normal cost of production or operation. On the other hand, reducing the noise of the feeding machine results in adding to the gross return.

A corresponding reduction in breakage or undergrade eggs and feed intake would seem to be the most easily explained change in performance. Problems with breakage are aggravated when hens are in flight or in frightened or nervous conditions. Sudden change in the excessive noise level could result in reduction of gross return per cage. Finally, it should be strongly emphasized that the noise level inside the poultry house must be not more than 55 dB, including all the noise originating from machinery.

The present author suggests that the noise level inside the poultry house should be measured daily as is being done with other environmental factors.

4.1.5. Mineral contents of the egg shell

The egg shell is a rather complex structure. There is much more involved in the maintenance of good egg shell quality than simply trying to secure a thick shell. The outer covering of the egg comprises 7 to 12 % of the total egg weight. The elemental composition of egg shells has been reported by ROMANOFF and ROMANOFF (1949) who found that the it consists largely of calcium carbonate with some magnesium carbonate and calcium phosphate. Most of the phosphate and magnesium is located in the outer portion of the shell, and the effects of these elements on shell quality are extremely small as compared to those of calcium.

The purpose of our experiments is to determine the effect of noise on the mineral contents of the egg shell and to evaluate the possibility of using the change in mineral composition as an indicator for stress.

The obtained results clearly demonstrated the effect of highway and feeding machine noise on the mineral contents of egg shells. In general, calcium, magnesium and phosphate concentrations were affected by the highway noise. Feeding machine noise only influenced the magnesium level, whereas calcium and phosphate remained at a relatively constant level. These results are not in agreement with the findings of KAZUSHI and SUGAWARA (1986) who noticed that there were no significant differences in the contents of calcium, magnesium and phosphate in the egg shell.

Previous reports have indicated a positive correlation between shell quality and calcium content of the shell (HOLDER, 1975; ATTEN and LEESON, 1983). Our own results indicated that shell quality was influenced by highway noise. This means that shells of eggs laid by hens in the control group had higher calcium content than those of the group treated with highway noise. However, the involvement of shell magnesium and phosphate levels in egg shell quality is not clear (BROOKS and HALE, 1955 ; HOLDER,1975).

The explanation of the present results is that the highway noise caused irritation and frightening of the hens. Hence, the hens were shown to lay eggs with thinner shell due to lower calcium content. Noise could also reduce calcium transport across the uterine mucosa or could change conditions of calcium deposition as taking place in the shell gland. The lack of calcium utilization in the uteri may induce hens to lay soft-shelled eggs (ROLAND et al., 1977). Moreover, the presence of excess noise could influence the absorption of dietary calcium from the food supply of the previous days. Furthermore, the results suggest that, since the egg remains in the shell gland for approximately 20 hours, noise stress might render the hens unable to withdraw sufficient calcium from the bones to produce a maximum shell thickness, thus giving rise to low calcium egg shells.

In this study the author particularly concentrated on the element calcium as (a) calcium is the major component of the egg shell weight consists of calcium carbonate and (b) there is a distinct relationship between calcium contents and shell quality.

The secretion of magnesium and phosphate in the uterus varies at various phases of shell formation and large quantities of both elements are secreted during the few hours of the oviposition. The processing of elemental secretion was clearly inhibited by noise stress.

4.1.6. Feather condition

Feather loss is important in relation to bird welfare. Moreover, the pecking and abrasion involved in feather loss are likely to be painful. Much work has been done in the past few years on the factors determining the plumage condition of the hens.

Climatic adjustment of the environment may sometimes provide a solution. An example thereof is increasing the relative humidity inside the house by regularly spraying a mist of water, when there is a risk of the air getting too dry and the feathers of the birds thus becoming increasingly brittle and more sensitive to physical damage (ANONYMOUS, 1983). Various other factors in the climate, such as temperature, light intensity, etc., are also mentioned to affect plumage condition. Noise too is an environmental factor which may affect feather condition.

The present study was carried out in order to investigate the influence of noise stress on the plumage condition.

From the results obtained it was concluded that, in most of the measurements made, the scores were generally higher in the control group than in the other groups. In the case of the noise produced by the feeding machine, it was found that the noise contributed to feather deterioration. Most parts of the body can be involved, but the part most frequently affected is the breast; the cause is often ascribed to abrasion against the cage front or the trough as during the noise exposure periods in particular. In the present case, highway and feeding machine noise distinctly led to increased feather damage, amounting to about 51 and 8.45 % in the respective cases. This study provides information on the fact highway noise caused hysteria among the hens. A hysterical episode is characterized by the hens suddenly wildly flying about; this episode may last for a few minutes or sometimes longer. In the case of the feeding machine noise, it was found that when the motor of the feeding machine started to operate, this caused nervousness, jumping or moving randomly for a few seconds whereas hysteria could be observed only very seldom. The latter phenomenon could arise in a situation where the feeding machine is old; it was observed in some of the poultry farms in Gent, Belgium.

Conversely, hysterical or nervous episodes would start when hens are disturbed by the noise of the highway or during feeding time. In those cases, the entire group was involved almost instantaneously, while at the same instant more pecking at the hens' own plumage or at that of the neighbours were observed. In those situations, hens showed more aggressiveness or were more fearful, and the activities described were enough to damage the plumage. This conclusion is supported by earlier research by RUZZLER and KIKER (1975) and by HANSEN (1976). CRAIG et al. (1983) noted that hens of a more nervous disposition had poor plumage whereas fearful hens also suffered greater feather damage and loss (HUGHES and DUNCAN, 1972).

As far as the egg producer is concerned, feather condition may be economically important because it is related with food cost which constitutes a major part of egg production cost. The present study showed that hens treated with highway and feeding machine noise consumed more food than the control group because they were characterized by a poor plumage condition or even a naked body (plate 3.1). The latter conditions are most probably indicators not of nutritional problems but of noise stress. These results are in agreement with the findings of TAUSON and SEVESOON (1980), who reported that unfeathered hens eat more than feathered hens. Thus, the importance of the plumage cover as a protector against extensive heat losses is very important for the food intake level.

In conclusion, hysteria, nervousness or fear in hens leads to the abrasion of the plumage and to feather pecking, these being the two main causes of feather damage. These kinds of behaviour cause the hens to make a number of movements inside the cage which are by themselves important enough to produce damage to the feathering.

It is necessary, that the noise level at least inside the poultry houses should be considered when plumage deterioration of caged layers is being discussed. It is important to the plumage of the hens as physically intact as possible, not only from the point of welfare of the hens, but also for reason of economical aspects of farm management.

4.1.7. Corticosterone levels in the hens' plasma

Change in serum corticosterone concentration is considered to be a valid indicator for physiological stress. Elevation of plasma corticosterone is associated with stress in laying hens (BEUVING and VONDER, 1978). DANTZER and MORMEDE (1983) concluded that, under closely controlled conditions, corticosterone concentrations can be a measure of the animal's perception of its environment, allowing this variable to be used for simple and practical evaluation of welfare (GIBSON et al., 1986).

The aim of this investigation was to study the noise produced by a feeding machine, and to assess the physiological response of laying hens to this stress through measurement of the corticosterone level in the plasma. In this study the feeding machine noise was classified as chronic intermittent stress; we call it "sudden noise" since it acts as an unexpected or surprise stress.

In general, if the stress situation is severe enough, many different response patterns can be demonstrated. This depends on many factors such as the type or duration of the stressor. In the case of noise, the noise level could be the major stressor. The physiological involvement of the individual animal has been discussed in detail by HENRY and STEPHENS (1977). According to their hypothesis, the physiological response to a stressor depends primarily on whether the animal is threatened, i.e. in danger of loosing control over the situation or whether it has already lost control.

In the present study the physiological response was observed when laying hens were surprised by feeding machine noise. When the feeding machine is operated, the hens at first respond with a reaction of the following type : flight, trying to escape, jumping more than once, or crowding at the rear of the cage. At the poultry farm most of the feeding machines are operated for a few minutes at different time intervals (3 - 5 times/day) depending on the feeding frequency or schedule. This implies that loss of control is no longer a mere threat but a reality.

After the behaviour fall the brain-pituitary cortico-adrenal axis is activated. This could be an explanation for the increase in corticosterone in the group treated with the stress and its release being the predominant physiological response. Noise causes a general stress effect as follows: paths are connected with the formatio reticularis. The formatio reticularis influences the sympathetic nervous system and with it the organs it innervates e.g. pupils, heart, digestive system, adrenal medulla and blood vessels as well as body musculature. Through the hypophysis, the hypothalamus gives signals to the adrenal medulla and the thyroid gland via ACTH (Adrenocorticotrophic) and TSH (Thyrotophin). The hormones regulated by the hypothalamus have an influence on the metabolism, the blood sugar regulation, the electrolytic balance and the genital functions (BORG and MOLLER, 1973). Also the parasympathetic nervous system is influenced by noise and has a mainly antagonistic effect compared to the sympathetic nervous system.

Hens treated with feeding machine noise and highway noise had significantly higher corticosterone levels than those in the control group. Highway noise at 95 dB acts as a major stressor on the group which was treated with this kind of noise. It results in stressful activities such as repeated handling, physical restraint, heat stress, and withholding of feed and water, reactions which have been shown to increase the corticosterone concentration in the plasma of chickens to 5 to 10 ng/ml (BEUVING, 1980). Thus highway noise stress was great enough to increase the corticosterone level in the group loaded with the noise.

The noise produced by the feeding machine could also induce an elevated level of corticosterone in the plasma level. However, this concentration could persiste in the plasma only for a period of about 9 weeks. After 10 weeks from the beginning of the experiment, the laying hens gradually adapted and showed less and less response by decreasing the hormone level in the blood. These results are in agreement with the findings of CRAIG et al. (1986), who reported that chickens housed in cages were showing declining levels of corticosterone in their plasma after adaptation.

With regard to the level of corticosterone in plasma, an interesting phenomenon occurs in poultry. In our experiments, laying hens required a period of 8 - 12 weeks to adapt to stress. Before the adaptation period laying hens suffered from the sudden noise of the feeding machine. However, not all the laying hens have shown the ability to adapt to the sudden noise. It can be said that some of them were at least suffering on a long term basis. Suffering cannot be directly observed but only inferred from corticosterone concentration measurement or any other indicator which allows assessment of the welfare of the laying hens. This phenomenon did not occur in the group loaded with highway noise where the raised corticosterone concentration remained as long as the noise existed. The noise of the highway caused painful stress and jeopardized the health as well. Moreover, noise generated by the feeding machine and highway increased the corticosterone levels by 20 and 70 % respectively with respect to the control group.

In conclusion, hens in the group exposed to highway noise stress may suffer continuously. However, those in the group subjected to feeding machine noise may suffer only occasionally. Therefore, it is necessary to minimize the level of exterior noise (highways, industry) in general, while keeping down the noise level inside poultry house should be one of the main building considerations. This can be done by designing new types of feeding machines which allow to maintain the level of noise pollution inside the poultry house below 55 dB, this level of noise being acceptable to the hens. The noise level outside the poultry house should not be more than 70 dB and hence, the poultry house must be constructed far away from main roads.

At this point, we are confronted with the question of wheather the welfare of the laying hens is affected. Physiological responses such as elevated plasma levels of corticosterone hormone can be elicited by either acute or chronic stressors. The results suggested though that there were positive correlations between noise stress and corticosterone concentration, which may therefore be considered as a physiological index of the welfare of hens. Hence it was concluded that the well-being of hens in the control group was better than those under noise stress.

Finally, the "optimal" use of the feeding machine viz. the feeding time should not be more than 10 minutes at the beginning of the housing, as at that time in particular the corticosterone concentration tends to increase with the duration of feeding times. This is no longer a serious problem, since the number of feeding times per day has been increased to more than the normal number, at the same time decreasing the feeding time length. After the original adaptation, the feeding programme can be returned to the normal. Our experiments indicate that both feeding machine and highway noise stress had a significant detrimental effect on the welfare of the laying hens.

4.1.8. Abnormal egg shells

One of the difficulties of assessing stress in poultry is that many of the methods for obtaining information themselves disturb the animal and thereby alter the characteristic which is being measured (FREEMAN, 1985). For instance, adrenocortical and thyroid hormones are physiological indicators of various forms of stress in the fowl (SIEGEL, 1975, 1980 ; WODZICKA-TOMASZESWSKA et al., 1982). However, since this method implies blood sampling, it could not be performed without considerable pain or stress to the hens. As the severity aspects of the stress response are considered undesirable, there is an urgent need for other suitable indicators which yield information concerning the welfare status of an animal under field conditions.

Egg shell abnormality is therefore potentially useful as a stress indicator without harming the hens. Better understanding of what is wrong with eggs which are abnormal may lead to understanding the effects of underlying stress factors such as noise. The objective of this study was to determine the effect of noise stress on the egg shell quantity, and to prove it is possible to use the egg shell abnormalities as an indicator of stress. Also the relation to the economic aspects was considered.

Eggs were examined and classified in six categories: normal, brown deposit, misshapen, chalky, dusty and other defective of egg shells (soft shell, shell-less or bulgy and white-banded egg shells). Eggs take approximately 26 hours to be formed and 10-17 hours of that time are spent making the shell. If so, eggs crack or ridge within the oviduct while still soft. Normally the hen will repair this before the egg is laid, but under the sudden noise of the feeding machine and the excessive noise of the highway this natural repair mechanism may be inhibited.

Abnormalities of egg shells have been studied in detail and documented photographically during the experimental period, with all the while the noise of a highway or a feeding machine acting as the stressor. The results showed that the noise stress not only affected egg production and level of the corticosterone in the hens' plasma, it also had a quantifiable influence on egg shell quality.

One of the egg shell abnormalities, which is described as rough shell calcification, usually appears in the form of a longitudinal band. These are so called bulgy eggs. The explanation for this abnormality is that during the production process, the egg went through a retention phase which resulted in the deposition of a coating of variable nature on the surface of the egg. Preliminary examination showed that this coating consists of amorphous calcium carbonate. These results are in agreement with the findings of VAN MIDDEKOOP (1971). The nature of this particular abnormality was dependent on the stage of egg formation at which the disturbance was imposed, and due to the inability of the laying hens to lay at the right time.

Disturbances at a time when eggs are only lightly calcified tend to result in misshapen eggs, while those occurring when oviposition was imminent tend to cause coated eggs. For example, dusted or chalky egg shells followed moderate retention, whereas white banded or bulgy eggs are found after prolonged retention. Shell-less or soft-shelled eggs, which are covered with little or no shell substance, are quite frequently produced by domestic fowls (HUGHES and PARKER, 1971). The total number of shell-less eggs laid by the group treated with noise was significantly higher than control. The cause of such abnormalities is that the hens got violent peristalsis which hastens the egg through this region before a shell can be formed. Another explanation added by HEWITT (1939) for the shell-less eggs was the failure of the glands in the shell-secreting portion of the oviduct. Noise disturbance releases adrenaline, which in turn causes contraction of the shell gland and can delay oviposition (SYKES, 1955 ; DRAPER and LAKE, 1967).

When both bulgy or white banded and shell-less eggs were laid close together, a probable explanation is that the bulgy egg shell had undergone a greater than usual retention resulting in a supplementary calcium carbonate deposit, a phenomenon which is frequently followed by the oviposition of a shell-less egg. These results are in agreement with the findings of HUGHES and PARKER (1971).

Regarding the feeding machine noise it was noted that the feeding periods were sometimes quite stressful, due either to noisy machinery or to too long a period between feeding so that the hens are too hungry and make more noise than normal. This noise stress then resulted in a banded and misshapen egg shell. Our assumption is that the change in ovulation timing as caused by noise stress might be responsible for all of the abnormalities described. However, when abnormalities keep occurring throughout the production period, this in itself leads to stress. The author therefore puts forward the idea that, in future, the evaluation of both machinery and highway noise should be awarded more attention. Not only should the feeding machine and all other equipment be well oiled, the time between feeding periods should be reduced as well.

Eventually, the abnormalities of egg shell were mainly associated with the presence of stress. It can be concluded that subjecting the hens to regular noise of a highway can induce more stress than intermittent machine noise.

The time of the day also affected the categories of abnormality produced. Most of the disturbances were applied during the day-time, particularly in the morning. In the morning, most of the hens had a fully shelled egg in the uterus. The predominant abnormality then was the coating over the cuticle, the incidence of misshapen or bulgy eggs being high. However, when the noise disturbance occurred over a long period of time, which extended well into afternoon, lightly shelled eggs would reach the shell gland, resulting in an increase in egg shell defects of other types.
The explanation of HUGHES et al. (1986) corresponds well with our results. The former research worker explained that hens laying early in the day would generally also have ovulated earlier on the previous day; their eggs would thus have reached

the shell gland, would have received a thin layer of calcium carbonate and would have been vulnerable to cracking and the formation equatorial bulges at a time when the disturbance was continuing. Hens laying later in the day, however, would have ovulated later the previous day and their eggs would not have reached the shell gland until after the disturbance had ceased. Eggs collected in the morning, therefore, would be more likely to show equatorial bulges or be otherwise misshapen than those collected in the afternoon.

Moreover, there is a positive relationship between noise level and the number of misshapen, brown deposit and other types of defective egg shells. This means that an increasing noise level resulted in a rise in the proportion of misshapen egg shells and egg shells with other defects.

The conclusion is that the problem of abnormalities of egg shells is very important to the poultry industry since the consumer will not buy eggs with defective shells. We made a statistical survey about the human disposition for buying 'abnormal eggs'. Analysis indicated following order of preference - i.e. with those abnormalities which were least likely to be bought put first : misshapen (36.5 %), bulgy (27.5 %), white-banded (20 %), brown deposit (11.5 %), chalky (2.5 %) and dusty (2 %). As the consumer demands high quality eggs and is interested in their nutritive value, defective eggs are an important cause of financial loss to the poultry industry. In addition, the loss may be greater than is realized, since some shell-less and soft-shelled eggs are neither collected nor recorded because they easily fall through the cage floors. The abnormalities may imply other losses as well. They may e.g. cause failure to reach setting-egg standards in eggs intended for incubation, a possible reason being plug material (very thick shell) which negatively affects the rate of the gas exchange into and out of the egg.

Finally, the results suggest that egg shell analysis may be another harmless method for determining stress in laying hens whereas its study may help to overcome the problem of the occurrences of declining egg shell quality.

In general, noise of the feeding machine and highway disturbance of the hen resulted in a premature oviposition and thus in a large percentage of egg abnormalities. If so, further "noise stress"-factors must be taken into account when determining the well-being of hens in battery-cages.

4.2. INFLUENCE OF VARIOUS FEEDER LENGTH-RELATED STRESS FACTORS ON THE LAYING HENS

4.2.1. Behavioural activities

Together with a gradual change towards more intensive keeping of laying hens in battery cages, the living conditions for these animals have evolved towards a system of minimal freedom. This evolution has been followed by a change in the animals' behaviour, both on a quantitative and a qualitative basis. Many researchers nowadays try to provide an answer to the question whether or not - from the animal's point of view - those behavioural changes have indeed decreased to such a great extent. A positive answer would actually imply that, under the restricting conditions of absolute confinement, the laying hens suffer and are caused a lot of harm. Evaluation of farm animal welfare is based on several factors among which behaviour. Behavioural measurements can provide a good indication of stress or response to it.

There are many different aspects of a battery cage environment which hens might potentially dislike or which might actually cause them to suffer. These include the small floor area of the cage, the sloping wire floor, the lack of a nest-box and lack of sand bathing substrate or the limited height of the cage. It has been noticed as well that often little attention was paid to provide an appropriate feeder length for each hen.

Most studies of cage density dealing with the factors group size and area per hen (CRAIG and ADAMS, 1984; OUART and ADAMS, 1982) have shown food trough space to have distinct effects on weight gain and economic factors as well as on behaviour. The European Council recommends a feeder length of 10 cm/hen or more and since 11 November 1989 a feeder length of 10 cm /hen was obliged in Belgium. At any rate, this recommendation does not consider the possibility that such a length of trough may not be enough for the welfare of the hen. The discussion on the subject of the most appropriate feeder length with regard to the hens' welfare is thus left open .

Our research in this area has concentrated on determining the most suitable feeder length per hen and to relate this measure to the well-being of the hen by using behaviour as an indicator.

As far as comfort behaviour is concerned, levels of activity differed markedly between the treatments. The behavioural activities of hens kept in cages with various feeder lengths, and related to average counts per hour, are summarized in table 3.16. Hens housed in cages with 12.5 cm feeder length per hen seemed to be more active in 6 out of the 7 recorded behaviour patterns (standing, sitting, wing/leg stretching, body shaking and preening) than the hens in other cages; an exception is made for head shaking, the incidence of which was higher in the type IV-cage (13.3 cm/hen).

Wing-flapping was rare, but then again this particular activity is infrequent under cage conditions. Several researchers who examined the influence of space restriction on wing flapping, clearly noticed a decrease in this activity in hens in cages (BRAMBELL, 1965; SODERKAT, 1980 ; and VERENA TEBBE, 1984). Wing flapping, was only observed in cages with a large floor area (NICOL, 1987). It is true that a commercial battery cage is not large enough to allow part of the full motor pattern to take place (DUNCAN, 1981).

The results show that when the feeder length is adequate the hens can behave well and synchronically. Hens in cages with feeder lengths of 12, 12.5 and 13.3 cm/hen have an increased motivation to preen ; head shaking was also more frequent when other hens were invisible. The counts per hour of sitting and standing activities were highest in the cages with feeder lengths of 12, 12.5 and 13.3 cm/hen feeder length, increasing with the increase in space per hen (presumably because there is more freedom to move). When available space is less, there is less incitement for the hens to move around, therefore the counts per hour of sitting decreases.

Head shaking behaviour occurred at a higher rate when companions were visible, thereby supporting HUGHES' (1983) hypothesis that it is an altering response. This activity may change with the visibility of companions (WOOD-GUSH, 1987). When there is more space, the visibility of companions is good and hens will use more time for self-directed activities, such as stretching or preening. The highest frequency of head shaking was observed in the cages with a feeder length of 13.3 cm/hen. Head shaking could also be a social signal (NICOL, 1988).

Increasing the feeder length caused a number of comfort activities to occur more frequently. The most unexpected consequence was that the hens in the cages with a feeder length of 13.3 cm/hen did not actually make use of all the available feeder space. This conclusion indicates that the amount of trough space is more than they need.

The results of the present experiment suggested that a feeder length of 12 cm/hen was most appropriate. Restricting the trough length to 10 cm/hen caused a lot of aggression. It is certainly true that aggression can be a result of frustration, meaning that the feeder length of 10 cm per hen was experienced by the hens as frustrating.

However, it is easy to say that an animal is frustrated in an extreme situation ; the main problem of interpretation arises though in that range of situations where one might say that only mild frustration occurs. In the case of 10 cm/hen feeder length and cage populated with 5 hens, there was a situation during feeding time when most of the time one of the five hens had to wait for one of others to finish before being able to start feeding itself. In this case it must be agreed that the isolated hen is frustrated, thus reflecting a typical welfare problems connected with keeping hens in cages.

Agonistic behaviour was also affected by the difference in available feeder length per hen. Feather or cage pecking and pushing behaviour were significantly more frequent among hens housed in cages with a feeder length of 10 cm/hen. It may be true that cages with 12 and 12.5 cm feeder length per hen may reduce peck opportunities and pushing behaviour. Most agonistic acts occurred during feeding activity (AL-RAWI and GRAIG, 1975), their frequency increasing with decreasing feeder space. In contrast, PRESTON (1983) found no relationship between the shape of cages or the number of birds on the one hand, and the frequency of agonistic feather pecking on the other hand. The severity of feather pecking behaviour was thought to increase with age, but unfortunately, no measurement of this was made.

We agree with WENNRICH (1974b) who found that food pecking behaviour can easily lead to feather or cage pecking or to pushing acts when only limited trough place is available, making it difficult for hens to feed simultaneously.

Pushing was observed in all cages. As could be expected, pushing occurred more frequently in the cages with inadequate feeder length (10 cm/hen), where body contacts were most probable and where locomotion was hindered. This result tends to support the assumption that pushing is performed in restricted or confined areas or in cages where trough space is limited. Pushing must therefore be considered a behaviour by which hens tend to support each other temporarily at the food trough. However, the fact that pushing appeared even in the cage with feeder length of 13.3 cm/hen (3 hens/cage), means that pushing behaviour was also affected by the activity of hens in the cage. It could be that, if hens are more active in a space which is larger than their actual requirements, this would result in increased movement and would lead both to more pronounced abrasion against the cage bars and to disturbing of the other hens in the cage.

It was observed that cage and feather pecking increased with reduced trough space per hen. The inadequate feeder length (10 cm/hen) evidently leads to a greater frequency and intensity of aggressive interaction.

Feeding activity was less frequent in cages with a feeder length of 10 cm/hen (type I-cage) than in the other cages ; limited space at the feeder probably made it difficult for all the hens to feed simultaneously, thus decreasing feeding activity in general.

Hens in cages of types II and III (12 and 12.5 cm/hen feeder length respectively) displayed significantly more episodes of synchronized behaviour activity than did the hens in the type I-cages, particularly with respect to feeding or drinking and preening. Adult fowl are known to display highly synchronized feeding activity as a result of both simultaneous physiological motivation and social facilitation (HUGHES, 1971).

It is difficult to draw direct comparisons with other investigations since hens behave differently in different environments. For layers, cages constructions can be varied in as many ways as the environment itself.They may differ in floor area, height and trough space. ROBINSON (1979) reported that feeder length per hen, colony size and floor area are the most important factors responsible for performance differences. In the studies reviewed, the effect seemed to occur over a wide range of feeder spaces. MEUNIER and FAURE (1984) found that free access to a 1 m food trough provided the hens with apparently ideal feeding conditions. In addition, CARD (1961) has pointed out that the optimal trough length per hen was much greater than the 14 cm available under normal husbandry conditions, or the 27 cm per hen as recommended by FAURE and MALLARD (1973).

In fact, a feeder length of 12.5 cm/hen was suggested by the present data, both as it is an economically justified solution and as we must emphasize that feeding activity is not the only behaviour to be considered when a specific feeder length is to be recommended. Other behavioural activities must indeed be taken into account. It was observed that, when increasing the feeder length up to 13.3 cm/hen (more than the hens need), the hens tended to play with the food rather than consuming it, resulting in an increased food loss. These results are similar to those of BARBATO et al. (1988), who indicated that increased feeding space leads to increased "feeding play".

Behaviour recorded at the feed trough consisted of the number of bouts, time spent as well as number of hens feeding together. This behaviour as such can be used as a welfare standard against which the birds' behaviour at different trough lengths can be compared. Thus, if the hens' behaviour at the trough differs markedly from their behaviour corresponding with a feeder length of 10 cm/hen (as recommended by the European Community and obliged in Belgium), it may be indicative of a change in their welfare.

It was observed in this study that increasing the food trough length per hen to 12.5 cm/hen affected feeding activities. These results are similar to those of CUNNINGHAM and VAN TIENHOVEN (1983), obtained on shallow cages. A positive relationship between available feeding space and time spent feeding has been demonstrated in our results ; these findings agree with those of HUGHES (1983). Increasing feeding time led to decreased feather pecking and/or cannibalism as observed in the cages with 12 and 12.5 cm/hen feeder length.

The time of day influenced the feeding behaviour too. This factor was also correlated with egg production by a change-over of the most common feeding time from the morning at pre-laying to the afternoon at peak-lay. The reason therefore could be that oviposition, which usually occurs in the morning, reduces the time spent feeding before midday (WOOD-GUSH and HORNE, 1970 ; SAVORY, 1977). Our results are in agreement with the findings of PRESTON (1983), who reported that the time of day and the hen's age interacted up to peak-lay.

An interesting result was that the highest average number of bouts and time spent in seconds was observed in the hens housed in the type I-cages (10 cm/hen). An explanation for this could be that hens in type I-cages have less food trough space so that their interaction viz. competition at the trough may increase. This means that weaker hens would have to wait till the others have finished feeding, after which the weak hens could feed at a late afternoon hour. The case was different with those housed in the cages other than type I since there they normally fed together during the early afternoon.

The results show significant differences between the treatments as far as drinking behaviour is concerned. Hens housed in cages of types II, III and IV (feeder lengths of 12, 12.5 and 13.3 cm/hen respectively) drank more than those in the type I-cages (10 cm/hen). The explanation is that hens in cages of types II, III and IV also eat more than the hens housed in cage of type I. It is true that the feeding and drinking intake are strongly correlated and both behaviours take place simultaneously (GOUSSOPOULOS et al., 1973) ; it could also be a social signal, indicating they have more opportunities to drink. A third explanation could be that the egg formation is also related with drinking behaviour.

4.2.2. Production activity

Judging the results presented in table 3.20, the feeder length appears to have had an effect on the numbers of eggs laid by the hens housed in cages with differences in feeder length. Feeder length placed stress on the hens, triggering off hormonal reactions, which affected the control mechanism of egg formation.

Hens housed in cages with feeder lengths of 12 and 12.5 cm/hen produced markedly more eggs than did those housed in cages with 10 cm/hen feeder length. However, extension of the feeder length up to 13.3 cm per hen did not solve the problem, but rather gave rise to even more negative results. The differences observed in egg production were due to a clear difference in the mortality of hens housed in the different cages.

Mortality of hens in cages with 10 cm/hen feeder length was nearly two times greater than among the hens housed in the cage with 12 and 12.5 cm/hen feeder length. The higher mortality rate might be due to the disturbance between hens as caused by all hens pushing towards the feed trough at the same time (competing for a feeding space). Sometimes the hens wanted to get through to reach the trough by throwing themselves on those in front with their wings spread. These movements lead to aggressiveness followed by feather pecking or sometimes cannibalism. Thus, more stress is added, eventually resulting in death. The observation of increasing mortality with increasing group size at a constant trough length per hen is in agreement with the result of ALBEN and PERRY (1975). The present results show that hens in type IV-cages have a high mortality percentage, the interpretation of which is that hens in cages with 13.3 cm/hen feeder length were more nervous and displayed more feather pecking.This behaviour eventually resulted in an increased mortality.

The feeder length had a significant effect on the frequency of dirty and broken eggs. The lowest percentages were found in cages with feeder lengths of 12 and 12.5 cm per hen ; the highest in the cages with 10 cm feeder length per hen. The availability of more feeder space per hen clearly took away the need for extra movement, pushing, competing for a feeding place or climbing on top of each other. The latter types of behaviour are by themselves enough to increase the frequency of dirty and broken eggs. These result are similar to those of ROLAND (1978), who reported that increasing bird density and population size resulted in more broken eggs. It was observed that hens in cages with feeder lengths of 12 or 12.5 cm/hen produced a greater egg mass and less soft-shelled eggs. These results are consistent with the findings of CUNNINGHAM (1982).

Hens in the cages with 12, 12.5 and 13.3 cm/hen feeder length used more feed and gain more body weight than the hens in the group provided with 10 cm/hen feeder length. These results correspond with the findings of OUART and ADAMS (1982), who claimed that increasing the feeder length from 30.5 to 50.8 cm resulted in a significant increase of the body weight (6.3 %). However, LEE and BOLTON (1976) reported that neither body weight nor weight gain of light-weight layers were significantly affected by cage shape.

There are several possible explanations for the present observations. Firstly, it could be that, with increased trough length allowance, there may have been less competition for feeding space. This implies that the hens are able to feed whenever they wish, rather than being obliged to feed whenever there is a vacant space at the trough. Secondly, it is possible that the hens experienced less need to move in the cage in order to feed or drink. Thirdly, there could be a relation with the reduction of the stereotyped movements of head shaking behaviour, which take up much time and energy. All these causes led to a lower use of energy for movement.

In addition to the facts mentioned above, the most important result was that it was physically possible for all the hens housed in cages with 12, 12.5 and 13.3 cm/hen to feed at the same time. Available feeder space clearly affected the maximum number of hens feeding together simultaneously. More birds (means 3.0 vs. 2.5) were observed feeding simultaneously in cages with 12 cm/hen feeder length than in those where only 10 cm feeder length per hen was provided. Even more hens were observed feeding together in cages with 13.3 cm/hen feeder length. Ample feeder space may thus resulte in less competition for feeder space in the cages with 12, 12.5 and 13.3 cm/hen feeder space. A reduction of the feeder length below 12 cm/hen is likely to be unacceptable for welfare considerations.

In conclusion, the factor responsible for the changes in the production parameters in the type II and III-cages, is most likely to be the feeding trough. CUNNINGHAM (1982a) comes to an essentially similar conclusion, and this was of course, the objective originally laid down by BELL (1972). Increasing the available feeding space, leads to an increase in egg production, food consumption, body weight gain and a depression in mortality (HUGHES, 1975 ; HILL, 1977).

The present results are not in agreement with the findings of HUGHES and BLACK (1976, 1977) and HILL and HUNT (1978). These researchers concluded that as the trough length was raised from 10 to 15 cm per bird, an increase in egg production and body weight would ensue, and the mortality rate would be lower.

However, our results showed that extension of feeder length up to 13.3 cm per hen did not solve the problem. In contrast, the results of SCHOLTYSSEK (1974), who tested various types of cages with group sizes of 2 to 6 hens, feeding trough length of 6 to 17 cm/bird and stocking rates of 360 cm^2 to 800 cm^2/bird, showed no significant differences in laying performance and mortality in respect of the different features giving the rise to the variations. Only a low positive correlation was found between trough length and laying rate ($r = 0.2$). On the basis of his investigations, SCHOLTYSSEK (1974) came to the conclusion that 10 cm could be regarded as a suitable trough length per hen. We do not know whether this was drawn based on an improvement in welfare - as the social structure of the group was altered in the experiments -, or whether it was supported by an improvement of food intake (feeder length).

The present author points out that increasing the feeder length up to 12.5 cm/hen could have a negative influence. The evidence is the indication that hens in the cages with 13.3 cm/hen feeder length were more nervous and displayed more feather pecking (leading to cannibalism and higher mortality).

As far as our data are concerned increasing the feeder length more than the hen requires results in a negative effect.

These was strong evidence that a feeder length of 13.3 cm/hen depresses the welfare because (a) the corticosterone level of the hens in that particular group was very high - even higher than in the group provided with 10 cm/hen, and (b) the hens in those cages were more nervous and aggressive, which caused a lower egg production.

In most European countries, including Belgium, it is probable that a majority of hens are housed at 450 cm^2 per hen and the length of the feeding trough amounts to 10 cm/hen.

The present investigations indicate that both 10 cm or 13.3 cm feeder length per hen are likely to have a harmful effect on the welfare of hens, since the hens housed in these cages reacted to stress originating from the dimensions of the feed trough. If the stress surpasses a certain level, the hen can no longer adapt, which results in heavy mortality and low production. Increasing the trough space with certain limit might result in less disturbance at times of intense feeding activity and thus in lower energy consumption and higher production through low mortality and a good feather condition. At the same time, the hens could select a place at the trough more easily without disturbing each other. The improved feathering might reduce heat loss from the hens.

Most likely the advantage of the proposed feeder length of 12 cm per hen is a combination of several of the above suggestions. Thus, a feeder length of 12 cm/hen was considered best and is recommended by the author. We cannot consider laying hens welfare without taking production and mortality into account. The author agrees with the conclusion of MOSS (1980) that production is an index of welfare but is affected by a very large number of different factors. We should not only discuss the space available to each hen, but also every other requirements of the hen. It is not just a question of quantity but also of quality.

4.2.3. Egg weight and quality

The term "shell quality" is frequently used as a synonym for "shell strength". Shell quality is affected by factors such as the strain of the hen (HAMILTON et al., 1979a), the nutritional regime (WOLFORD and TANAKA, 1970), disease status (FRAZIER, 1972), temperature and humidity of the laying house (ANONYMOUS, 1972 ; MUELER, 1959), and the design of the cage systems (BEZPA et al., 1972). Shell damage in domestic egg production affects the income of the producers. This damage is assumed to be related to egg shell quality.

The purpose of the present experiment was to determine whether egg quality is influenced by the feeder length.

Average egg weight was affected by various feeder lengths. This result is similar to the findings of CUNNINGHAM and OSTRANDER (1981). They indicated that the eggs from hens in shallow cages were significantly heavier than those laid by hens in deep cages. In contrast to those results, BOLTON (1976) reported white leghorn strain housed in deep cages produced heavier eggs than when housed in shallow cages. The explanation for the larger size of the eggs produced in type II, III and IV-cages is the possible relation with feed intake.The hens housed in cages with various feeder lengths were not different from each other with respect to shell thickness, shell deformation, and shell weight and percentage. A similar trend was present in the findings of MUIR and GERRY (1976). Like some others (e.g. LEE and BOLTON (1976), these authors detected no differences in shell thickness between eggs from hens in deep and shallow cages.

Blood and meat spots are the most important traits of egg quality. These traits affect consumer demand for eggs. The present investigation demonstrated that the incidence of blood and meat spots was influenced by feeder length. The highest frequency of blood and meat spots was recorded on eggs laid by the hens housed in I-cage (10 cm/hen feeder length). Blood and meat spots percentages were also high in eggs produced by hens in cage of type IV, with 13.3 cm/hen feeder length. These results are in agreement with those of HILL and HUNT (1978), who found that the incidence of blood spots was significantly higher in hens caged in shallow cages (15.2 cm/hen feeder length) than in deep cages (10.2 cm/hen feeder length).

HILL (1977) also noted that increasing the space allowance per bird decreased the occurrence of blood spots. The only explanation for this is that increasing the feeder length more than the hens need, may have a negative effect and be frustrating for the hen.

4.2.4. Plumage condition

Feather pecking and abrasion are the two main causes of feather loss in caged layers (see e.g. TAUSON (1984)). HUGHES (1985) concluded that feather pecking is the most important cause of feather loss in multiple bird cages. Various studies have been attempted to relate the cage design to the feather loss. For instance, HUGHES and BLACK (1976) and TIND (1985) reported that the cage shape affects feather loss in hens. The amount of work related to factors affecting the plumage condition appears to be quite large and relates to the influence of temperature or relative humidity in the house, to the activity of the birds used in the experiments and other aspects.

The differences in plumage condition between the experimental treatments were associated mainly with feeder length. Hens housed in cages with 12 or 12.5 cm/hen feeder length had constantly higher feather scores whereas, on average, hens in cages with 10 cm/hen feeder length had a poor feather condition. The latter situation attributed to greater competition and nervousness among the hens. Contrary to our own results, OUART and ADAMS (1982) stated that mean feather scores were not significantly affected by the amount of feeder space.

Experimental evidence supported the conclusion that hens had a good feather condition when housed in cages providing adequate feeder length. However, lower feather scores were recorded when feeding space was increased to 13.3 cm/hen, which contradicts the general trend of results mentioned higher. In conclusion, our findings indicated that a feeder length of 12 cm/hen allowed the hens to keep themselves busy feeding instead of pecking at the feathers of their neighbours. Another advantage of 12 cm/hen feeder length is the decline in competition among the hens.

On the whole, feather damage can be extremely costly to the farmer because this phenomenon gives rise to an increased heat loss and consequently to a rising food intake.

Finally, the conclusion of the results is that, whenever hens get adequate feeder length, this has a general effect of calming down the hens. The lower level of movement activity prevents abrasion, thus causing less feather damage and reducing both the incidence of feather pecking among hens and the act of self-pecking. A relationship between feeder length and feather condition issued from the analysis of the experimental results. Thus, from a point of view of animal welfare, we have suggested that the cage with 12 cm feeder length and 506 cm^2 floor area per hen was suitable.

4.2.5. Serum corticosterone concentration

In literature adrenal hormones have often been related to stress and sometimes equalized as stress. FREEMAN (1978) said that the key to the response to stressors are the adrenal glands: no matter what stressor, these glands are stimulated and thereby regulate the response to the stressor. Other studies have been undertaken to determine the influence of population density on corticosterone concentration. The decrease in performance of poultry as a result of population density increase could be the result of physiological stress. Elevated plasma corticosterone levels have been associated with thirst, hunger and heat stress in laying hens (BEUVING and VONDER, 1978).

The objective of the present work was to determine the physiological response of laying hens to different feeder length.

The findings of this study indicate that the corticosterone concentrations in the plasma of the hens housed in cage of types II and III, with 12 and 12.5 cm/hen feeder length respectively, were consistently lower than those housed in type I and IV-cages with 10 and 13.3 cm/hen feeder length respectively. From the results obtained in this study, it is understood that the group housed in type I-cages was subject to more stress than the hens housed in type II and III-cages.

In conclusion, we can say that there was a decrease in blood plasma concentrations of corticosterone with increasing feeder length. However, this relation breakdown in cages with 13.3 cm/hen feeder length.
Feeder lengths of 13.3 and 10 cm/hen increased the hormone concentration by approximately 27 and 22 % respectively, as compared to the concentration in hens

housed in cages with 12 cm feeder length per hen. This implies that increasing the feeder length to 13.3 cm, exerts an unwanted influence on the hens' welfare. It may be that this length is actually more than the hens need. On the other hand, in order to minimize the physiological response to feeder length stress, a feeder length greater than 10 cm/hen should be considered when housing layers in cages, since a feeder length of 10 cm/hen may depress the hens' welfare. Hens housed in cages with feeder lengths of 12 and 12.5 cm/hen never showed high plasma corticosterone, this fact being a sound indicator of their greater well-being than their counterparts in cages with 10 or 13.3 cm/hen feeder length. To conclude we can state that inadequate feeder length frustrates the hens, which responded to suchlike situations by changes in plasma corticosterone concentration.

From the above grounds, it is clear that a feeder length of 12 cm/hen was the best for laying hens. This cage length was unlikely to have any harmful effect on welfare in battery condition ; it proves to be appropriate and was characterized by the hens in that treatment displaying the lowest level of corticosterone. However, it must be emphasized that these arguments should not be used as a justification for reducing the floor surface area per hen. Feeder length, floor area and number of hens per cage may, in the final analysis, be more important in terms of poultry welfare.

4.2.6. Economy

The potential profits of a laying hen operation depend on the biological response of laying hens both to their environment and to economically imposed restrictions. However, the poultry farm manager has almost no control over either the economic aspects of feed or egg prices.

Commercial egg producers continue to increase laying hen stocking density as a means of reducing investment costs per hen housed. Unfortunately, decreasing bird area often results in lower egg production (GOODLING et al., 1982) and higher mortality (OSTRANDER, 1982). It is thus understood that a greater number of hens per cage does not necessarily correspond with a greater profit. BELL and SWANSON (1975) have indicated that it is difficult for some poultry managers to visualize that fewer hens can make a higher revenue than a more crowded flock.

Egg price, hen income and feed costs were based on Belgian prices during the experimental period.
Hens in cages with a feeder length of 12 cm/hen returned 55.72 BF compared with 49.03 BF by those in cages with a feeder length of 10 cm/hen (both cage types

contained five hens). These respectable benefits are due to low mortality and high egg production. However, increasing the feeder length to 13.3 cm/hen (3 hens per cage) caused financial damage in reducing the return to 33.99 BF/cage.

Eventually, the stocking density of 5 hens per cage with floor area of 506 cm^2, and an allowance of 12 cm/hen feeder length, was economically better than 5, 4, 3 hens per cage with respective floor areas of 450, 506, 506 and feeder lengths of 10, 12.5 and 13.3 cm/hen.

The conclusion of our analysis is that both an increase or a reduction of the feeder length above or below the hens' requirements led to a reduction in gross return per cage.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. NOISE STRESS

Increased levels of ambient noise in the modern world may affect animal performance, cause economic damage and become an increasingly large environmental problem. Therefore, we should consider this kind of problem during our life and in raising domestic livestock.

The environmental conditions of domestic animals have changed sharply during the last two decades. For instance, the increased installation inside the poultry house of cleaning or feeding machines has resulted in ever more noise disturbances.

Inside poultry houses a large number of parameters are under constant supervision, such as temperature, humidity and air velocity. So far no method for measuring the noise level in poultry houses has been established. Nevertheless, this measurement should be carried out to at least provide an idea of the level and the character of noise in different houses. As mentioned above, noise levels in modern poultry houses are regularly high due to ventilation systems or to operation of feeding and cleaning installations.

For some of these disturbing elements, more or less straightforward solutions can be proposed. Excessive noise from high-speed fans, which are often placed inside the poultry house, can be damped using sound absorbent materials in the construction of the housing and the fans themselves.

In certain cases, feeding installations produce sound-levels up to 80 dB. These appliances usually have two noise-sources: the motor and the chains operating inside the trough. If these parts are old and not well-maintained, the resulting noise level - in particular when combined with the other noise inside the house - may reach a harmful high. Yet, it has often been observed that the placement of feeding motors was done without taking the presence of the hens into account. It is evident that suchlike considerations should be made when planning new poultry houses and related installations placed near or outside the house.

The present author concludes that the noise level inside the poultry house is bound to cause a lot of damage to the laying hens. The investigation presents evidence to prove that noise increases stress and depreciates the welfare of the laying hens. For example, a decrease in egg quality or increase in the corticosterone concentration in the plasma was observed in noisier environments.

A conclusion of possible interest for future investigations was that the measurement of the corticosterone concentration in the plasma could be a valuable procedure for the assessment of the relationship between noise stress and the cellular activities, the latter in relation to RNA and corticosterone levels in particular.

The maximum permissible in noise level determined by this study in a poultry house with batteries is not more than 50 - 55 dB. Above this level, noise is likely to give a stress reaction and is thereby detrimental to production, behaviour, egg quality, feathering, economic factors and health.

The author recommended the establishment of a standard value of the noise level inside the poultry house. In addition, this value should be recorded daily like other environmental factors. As consequences laying hens would be protected from noise pollution. The investigator further suggests that a legal standard of noise level inside the poultry house should be established. It is left to the European Commission to lay down regulations for noise pollution inside the poultry house alongside existing directives concerning other environmental factors.

5.2. THE LENGTH OF THE TROUGH

Serious discussion on the welfare of farm animals started about 25 years ago. Most of the poultry welfare experiments are related to housing systems and they are conducted in the Council of Ministers of the European Community. This institution has published a directive concerning the minimum space requirement for laying hens cages. As minimum space requirement, the directive demands 450 cm^2 cage floor area per hen and 10 cm feed trough length/hen. Regarding the floor area, DAWKINS and HARDIE (1989) proved though that a surface area of 450 cm^2 was inadequate for hen welfare.

The author points out the necessity to develop an improved cage which is justifiable from the point of view of animal welfare, and which relates to the minimal standards set up by the European Commission concerning basic feeder length per hen and freedom to express the normally acceptable patterns of behaviour.

The experimental results indicated that, based on performance indicators such as feeding activity or feather damage, 10 cm/hen feeder length was insufficient for laying hens. This conclusion was supported by the fact that the hens housed in such cages had high levels of the corticosterone. This means that the hens were frustrated, in which case welfare of the hens is deemed to be poor.

On the other hand, there was evidence that cage with 12 cm/hen was a suitable feed trough length and floor area of 506 cm^2/hen with density of 5 hens per cage. The advantage of this length against the 10 cm/hen is the increase of the available feed trough space per hen, reducing competition between hens, allowing both greater freedom of movement for the hens during feeding time and a production with greater economic efficiency, since in the wider cages the mortality rate was lower and at the same time egg production was higher, thus leading to an increased egg profit.

Finally, by no definition of the term can 10 cm/hen and 450 cm^2 floor area/hen be said to give adequate freedom during feeding time and not depress the welfare of the laying hens. The latter statement has been drawn earlier by DAWKINS and HARDIE (1989). The data showed many indicators of poor welfare, such as high mortality caused by feather pecking or cannibalism. One consequence of this is that in the assessment of systems for keeping animals, a wide range of welfare indicators should be used in order to decide on the appropriate feeder length.

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Appendix 1

Effect of noise level (dB) on the frequency of meat and blood spots on 90 eggs for each level (means ± standard error)

Noise level (dB)	Meat and blood spots %
60	5.08 ± 0.93
65	10.66 ± 0.8
70	14.5 ± 1.36
75	16.9 ± 1.58
80	19.7 ± 1.53
85	22.9 ± 2.41
90	21.5 ± 2.02
95	30.2 ± 2.14

Appendix 2

Influence of noise on comfort behaviour (activities counts per hour). Results represented as means ± standard error (n = 30) during one hour of observation

Comfort behaviour (counts/hour)	Control group (a)	Feeding machine noise (b)	Highway noise (c)	Level of significance ab	ac	bc
Head shaking	14.15 ± 1.54	11.75 ± 0.75	4.80 ± 1.30	**	***	***
Body shaking	2.20 ± 0.34	2.26 ± 1.21	0.41 ± 0.13	N	***	***
Wing/leg stretching	3.35 ± 0.74	2.90 ± 0.62	0.80 ± 0.21	N	**	**
Turning	1.03 ± 0.97	0.95 ± 0.19	0.25 ± 0.10	N	**	**
Sitting	8.15 ± 1.11	5.82 ± 0.94	2.20 ± 0.68	*	***	**
Standing	13.11 ± 0.88	13.71 ± 1.13	3.11 ± 0.61	N	***	***
Preening	13.35 ± 1.9	13 ± 8.16	4.75 ± 0.43	N	***	***

** $p < 0.01$

*** $p < 0.001$

N non significant

Appendix 3

Effect of noise stress on the time spent in seconds for the comfort behaviour per one hour of observation (n = 30). Results represented as means and standard error

Comfort behaviour (counts/hour)	Control group (a)	Feeding machine noise (b)	Highway noise (c)	Level of significance ab	ac	bc
Wing/leg stretching	95 ± 6.55	72.53 ± 4.64	36 ± 2.8	**	***	***
Sitting	325.15 ± 24.16	287 ± 24.68	100.4 ± 4.41	***	***	***
Standing	411 ± 28.16	493.33 ± 35	159.15 ± 5.7	**	***	***
Preening	254 ± 15.38	240 ± 21.39	93.65 ± 3.37	**	***	***

** $p < 0.01$
*** $p < 0.001$

Appendix 4

Mean frequencies of agonistic behaviour counts per hour affected by noise of highway and feeding machine (n = 30)

Agonistic behaviour counts/hour	Control group (a)	Feeding machine noise (b)	Highway noise (c)	Level of significance ab	ac	bc
Floor pecking	3.2 ± 0.49	5.32 ± 1.0	10.6 ± 1.04	N	***	**
Cage pecking	11 ± 2.37	28.2 ± 6.3	37.1 ± 6.7	***	***	**
Trough pecking	10.6 ± 1.98	15.32 ± 1.6	20.68 ± 2.38	N	*	*
Feather pecking	7.6 ± 1.37	17.9 ± 2.4	23.4 ± 6.1	*	***	**
Pushing	7.56 ± 1.24	21.52 ± 4.79	36.18 ± 5.79	***	***	**

* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$
N non significant

Appendix 5

Effect of various noise levels on agonistic behaviour (counts/hour).
Results represented as means ± standard error (n = 30)

Noise level	Floor pecking	Cage pecking	Trough pecking	Feather pecking	Pushing
60	0.30 ± 0.22	5.00 ± 0.68	6.00 ± 0.74	2.80 ± 0.70	0.31 ± 0.06
65	0.90 ± 0.44	11.00 ± 1.41	8.30 ± 1.50	3.00 ± 0.68	26.1 ± 3.12
70	4.20 ± 0.50	13.70 ± 2.01	11.70 ± 1.53	3.11 ± 1.47	4.90 ± 1.00
75	1.20 ± 0.31	12.30 ± 2.06	10.90 ± 2.61	2.85 ± 0.40	2.20 ± 0.65
80	8.90 ± 1.53	19.20 ± 1.53	16.30 ± 2.60	5.83 ± 0.48	11.60 ± 2.29
85	2.60 ± 0.76	24.40 ± 2.33	17.10 ± 2.13	29.30 ± 0.98	5.13 ± 0.92
90	2.30 ± 0.56	30.01 ± 1.98	20.30 ± 1.80	25.50 ± 2.66	3.31 ± 0.79
95	1.60 ± 0.33	41.60 ± 1.88	25.10 ± 2.53	30.10 ± 1.16	6.31 ± 1.22

Appendix 6

Mean frequencies of abnormal behaviour acts as affected by noise level (n = 30)

Abnormal behaviour count/hour	Control group (a)	Feeding machine noise (b)	Highway noise (c)	Level of significance ab	ac	bc
Feather pecking	7.6 ± 1.37	17.92 ± 2.36	23.5 ± 6.1	*	**	N
Cannibalism	1.3 ± 0.14	2.9 ± 0.58	7.3 ± 0.87	*	**	**
Jumping more than once	1.9 ± 0.2	5.0 ± 0.27	10 ± 0.96	*	**	*
Moving randomly	2.72 ± 0.76	6.7 ± 0.98	9.12 ± 1.88	*	*	N
Head pecking	4.2 ± 0.18	7.1 ± 0.99	15.2 ± 1.08	*	***	**

* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$
N non significant

Appendix 7

The incidence of feather pecking and moving randomly behaviour (per 60 minutes) at various noise levels (60-95 dB)

Noise level	Feather pecking	Moving randomly
60	2.80 ± 0.70	2.30 ± 0.80
65	3.00 ± 0.68	2.00 ± 0.50
70	3.11 ± 1.47	3.60 ± 0.49
75	2.85 ± 0.40	5.90 ± 1.29
80	5.83 ± 0.48	6.30 ± 1.30
85	29.3 ± 0.98	10.83 ± 1.40
90	25.50 ± 2.66	12.35 ± 0.72
95	30.10 ± 1.16	15.16 ± 0.60

Appendix 8

Plasma corticosterone concentrations change in response to the level of highway noise (60 - 95 dB). Samples obtained from 30 hens. Results represented as means ± standard error

Noise level (dB)	Hormone level (ng/ml)
60	2.08 ± 0.01
65	2.84 ± 0.15
70	3.12 ± 0.23
75	4.33 ± 0.21
80	6.16 ± 0.37
85	7.43 ± 0.22
90	7.82 ± 0.32
95	9.19 ± 0.52

Appendix 9

Corticosterone concentration in groups subjected to feeding machine noise during 6 different periods of exposure. Exposure time: from 10 up to 60 minutes; four repetitions for each period (n = 30)

Noise level (dB)	Hormone level (ng/ml)
10	3.01 ± 0.17
20	3.56 ± 0.23
30	3.50 ± 0.25
40	4.12 ± 0.54
50	4.25 ± 0.83
60	4.99 ± 0.48

Appendix 10

Relationship between highway noise levels (60 - 95 dB) and normal, abnormal egg shells (%) produced by 90 hens exposed to different noise level (dB)

Noise level (dB)	Normal egg	Brown deposit	Mishapen	Chalky	Dusty	Other defects
60	81.35	1.99	6.66	3.0	3.50	3.50
65	80.66	2.10	7.33	3.5	3.20	3.21
70	78.75	3.50	9.16	2.5	2.59	3.50
75	76.50	3.00	11.11	2.1	1.79	5.50
80	75.30	2.30	12.00	2.7	3.00	4.70
85	71.00	4.70	12.30	2.6	1.70	10.15
90	63.00	5.10	13.85	4.0	3.90	13.50
95	68.00	4.00	14.50	3.0	5.00	13.90

Appendix 11

Incidence of normal and abnormal egg shells from hens exposed to feeding machine and highway noise. Results represented as means ± standard error (n = 90)

Parameters	Control (a) %	Feeding machine noise (b) %	Highway noise (c) %	Level of significance ab	ac	bc
Normal eggs	90.16 ± 0.38	81.96 ± 1.3	71.56 ± 1.11	**	***	***
Brown deposit eggs	1.51 ± 0.73	2.08 ± 0.57	4.43 ± 0.35	N	**	**
Misshapen eggs	2.1 ± 1.03	4.94 ± 0.8	7.55 ± 1.1	**	***	**
Chalky eggs	1.90 ± 0.44	3.26 ± 0.23	4.25 ± 0.23	N	**	*
Dusty eggs	1.89 ± 0.5	3.32 ± 1.08	5.4 ± 1.47	N	**	**
Other eggs	2.44 ± 0.78	4.44 ± 0.27	6.81 ± 0.28	*	**	**

Other (soft shell, shell-less, bulgy, white banded)
* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$
N non significant

Appendix 12

The regression of abnormal and normal eggs produced by hens treated with different noise level of highway (60 - 95 dB) and n = 200.

Y	=	A	+	BX	Correlation coefficient r	
Normal eggs		121.2		-0.62	0.95	**
Brown deposit eggs		-2.56		0.07	0.68	*
Misshapen eggs		-7.18		0.23	0.94	**
Chalky eggs		2.29		8.09	0.16	N
Dusty		0.771		0.030	0.33	N
Other		-14.59		0.27	0.89	**

* $p < 0.05$
** $p < 0.01$
N non significant
Other (shell soft, shell-less, bulgy, white banded)

Appendix 13

Effect of noise on mineral composition of egg shell in laying hens.
The results represent as means ± standard error (n = 100)

Minerals (%)	Control (a)	Feeding machine noise (b)	Highway noise (c)	Level of significance		
				ab	ac	bc
Ca	34.49 ± 0.71	33.45 ± 0.41	29.63 ± 0.48	N	***	**
Mg	0.5 ± 0.06	0.44 ± 0.09	0.30 ± 0.01	*	*	*
P	0.048 ± 0.1	0.045 ± 0.15	0.037 ± 0.20	N	*	*

* $p < 0.05$

** $p < 0.01$

*** $p < 0.001$

N : non significant

Appendix 14

Effect of feeder length on comfort behaviour (activity counts per hour). Results represented as a means ± standard error (n = 30)

Activities counts per hour	Feeder length types I-cage	II-cage	III-cage	IV-cage
	10 cm/hen	12 cm/hen	12.5 cm/hen	13.3 cm/hen
Sitting	4.00 ± 0.57	8.86 ± 0.45	11.04 ± 0.60	10.75 ± 0.82
Standing	7.00 ± 0.85	13.56 ± 1.66	15.00 ± 1.54	12.63 ± 1.62
Wing-leg stretching	1.20 ± 0.15	3.46 ± 0.10	4.45 ± 0.30	3.31 ± 0.95
Head shaking	5.75 ± 0.50	10.37 ± 1.20	9.44 ± 0.69	11.76 ± 0.76
Body shaking	1.59 ± 0.40	3.81 ± 0.30	3.96 ± 0.39	2.14 ± 0.35
Wing flaping	-	-	-	-
Preening	6.38 ± 0.58	10.58 ± 0.90	12.77 ± 0.72	9.48 ± 0.75

Appendix 15

Influence of feeder length stress on the feeding behaviour measured (means ± standard error) number of feeding bouts, feeding time (in seconds) and numbers of hens feeding simultaneously per hour (n = 30)

Observation hour	Parameters	Type of feeder length			
		I-cage 10 cm/hen	II-cage 12 cm/hen	III-cage 12.5 cm/hen	IV-cage 13.3 cm/hen
8	no. of bouts	14.1 ± 0.75	25.6 ± 0.90	24.7 ± 1.11	20.6 ± 0.68
	time spent in sec.	849.0 ± 11.60	1 033.0 ± 19.60	1 106.0 ± 16.60	909.0 ± 10.50
	no. of hens feeding together	2.5 ± 0.30	3.3 ± 0.45	3.7 ± 0.15	2.8 ± 0.06
10	no. of bouts	12.8 ± 1.90	17.9 ± 0.10	16.4 ± 0.55	16.8 ± 0.60
	time spent in sec.	562.0 ± 7.30	733.0 ± 7.50	629.0 ± 12.60	691.0 ± 13.00
	no. of hens feeding together	2.2 ± 0.48	3.1 ± 0.35	3.5 ± 1.20	2.2 ± 0.30
12	no. of bouts	20.9 ± 0.99	30.6 ± 1.50	28.7 ± 1.45	41.4 ± 1.59
	time spent in sec.	1 171.0 ± 25.00	1 331.0 ± 21	1 448.0 ± 8.40	1 390.0 ± 21.60
	no. of hens feeding together	2.5 ± 0.60	3.7 ± 0.43	3.9 ± 0.10	2.5 ± 0.92
14	no. of bouts	15.9 ± 0.10	18.8 ± 0.86	18.1 ± 0.20	15.0 ± 0.80
	time spent in sec.	1 041.0 ± 14.30	1 078.0 ± 20.00	1 306.0 ± 25.70	1 390.0 ± 16.70
	no. of hens feeding together	2.7 ± 0.30	2.9 ± 0.76	3.2 ± 0.40	1.9 ± 0.40
18	no. of bouts	10.9 ± 0.80	8.4 ± 1.20	7.2 ± 0.70	6.3 ± 0.40
	time spent in sec.	766.0 ± 16.10	478.0 ± 18.00	623.0 ± 7.20	444.0 ± 16.10
	no. of hens feeding together	2.6 ± 0.70	2.0. ± 0.80	2.5 ± 0.52	1.2 ± 0.20

Appendix 16

Means and analysis of variance for number of pecks and time spent drinking (in seconds) of 30 hens caged in cages with different feeder length

		Treatments						
Observation	Parameter	I-cage 10 cm/hen	II-cage 12 cm/hen	III-cage 12.5 cm/hen	IV-cage 13.3 cm/hen	MS	F	
8	No. of pecks	3.59 *b*	8.53 *a*	7.78 *a*	4.55 *c*	2.0574	14.128	**
	Time spent	151.92	161.91	165.20	171.21	508.9015	0.640	N
10	No. of pecks	3.51 *b*	4.65	5.04	5.58 *a*	1.5737	2.453	N
	Time spent	134.00	147.36	144.20	135.20	237.1276	0.901	N
12	No. of pecks	4.93 *b*	8.44 *a*	7.53 *a*	6.38 *b*	2.1641	5.314	**
	Time spent	129.00 *b*	242.20 *a*	193.20	187.00	2 529.9254	4.247	*
14	No. of pecks	2.89	3.36 *a*	2.362 *c*	2.012 *b*	0.2468	7.121	**
	Time spent	121.00	159.21	139.20	129.00	1 514.860	0.884	N
18	No. of pecks	2.75 *a*	1.56 *d*	1.30 *c*	1.21 *b*	0.2020	12.693	**
	Time spent	151.92 *a*	161.91 *c*	165.20 *ac*	171.21 *b*	508.9015	0.640	**

Means followed by different italic letters are statistically different with significance level $p < 0.05$

* $p < 0.05$ ** $p < 0.01$ N non significant

Appendix 17

Means and standard errors per hour of the frequency of agonistic behaviour for hens under different feeder length (n = 30)

Activities counts per hour	Feeder length types I-cage 10 cm/hen	II-cage 12 cm/hen	III-cage 12.5 cm/hen	IV-cage 13.3 cm/hen
Cage pecking	20.58 ± 1.40	17.17 ± 0.95	11.03 ± 0.7	14.75 ± 1.54
Feather pecking	20.30 ± 1.15	9.08 ± 0.88	7.70 ± 0.56	12.50 ± 1.20
Pushing	24.36 ± 1.60	7.11 ± 0.90	7.37 ± 0.50	9.46 ± 0.98

Appendix 18

Production performance of layers in cages when kept at different feeder length. The results represented as means ± standard error (n = 120)

	Feeder length types			
	I-cage	II-cage	III-cage	IV-cage
Traits	10 cm/hen	12 cm/hen	12.5 cm/hen	13.3 cm/hen
Egg production (%)	73.81 ± 0.38	78.66 ± 0.40	80.34 ± 0.46	75.08 ± 0.39
Egg mass (g/hen/day)	43.27 ± 0.20	45.05 ± 0.36	47.37 ± 0.24	44.24 ± 0.30
Dirty and broken eggs (%)	7.44 ± 0.50	2.81 ± 0.26	2.34 ± 0.30	5.86 ± 0.46
Mortality (%)	8.00 ± 0.10	3.00 ± 0.26	2.00 ± 0.15	7.00 ± 0.40

Appendix 19

Means and standard error for feed consumption and conversion, body weight and weight gain by different feeder length (n = 120)

	Feeder length types			
Trait	I-cage 10 cm/hen	II-cage 12 cm/hen	III-cage 12.5 cm/hen	IV-cage 13.3 cm/hen
Feed consumption (g/hen/day)	111.08 ± 0.86	112.96 ± 0.79	113.83 ± 1.15	114.30 ± 0.90
Feed conversion	2.64 ± 0.20	2.33 ± 0.05	2.45 ± 0.03	2.71 ± 0.10
Body weight (kg)	2.10 ± 10.90	2.19 ± 5.50	2.09 ± 12.30	2.21 ± 11.90
Weight gain (g)	188.04 ± 3.90	235.04 ± 1.60	224.70 ± 1.60	210.50 ± 1.20

Appendix 20

The effect of feeder length on egg quality characteristics. Results represented as means ± standard error (n = 90)

Trait	Feeder length types			
	10 cm/hen	12 cm/hen	12.5 cm/hen	13.3 cm/hen
Egg weight (g)	61.25 ± 0.05	64.40 ± 0.40	65.88 ± 0.04	64.27 ± 0.55
Shell deformation (millimicrons)	16.05 ± 0.49	15.56 ± 0.40	15.62 ± 0.37	17.41 ± 0.50
Shell thickness (mm)	0.351 ± 0.38	0.352 ± 0.22	0.344 ± 0.40	0.341 ± 0.40
Shell weight (g)	4.62 ± 0.11	6.16 ± 0.06	6.20 ± 0.05	5.20 ± 0.10
Percent shell	7.53 ± 0.12	9.45 ± 0.60	9.20 ± 0.30	8.32 ± 0.08
Meat and blood spots %	9.80 ± 3.10	4.80 ± 2.20	4.20 ± 1.40	8.90 ± 0.50

Appendix 21

Means and standard errors of feather scores for hens under feeder length stress by total and single methods with average of both methods and significant differences between them (n = 120)

Body part	Feeder length types			
	I-cage 10 cm/hen	II-cage 12 cm/hen	III-cage 12.5 cm/hen	IV-cage 13.3 cm/hen
Neck	2.17 ± 0.11	2.99 ± 0.04	3.75 ± 0.03	2.08 ± 0.15
Breast	1.87 ± 0.15	2.80 ± 0.45	3.45 ± 0.10	1.79 ± 0.10
Back	1.95 ± 0.13	2.84 ± 0.05	3.55 ± 0.05	2.11 ± 0.70
Wing	2.00 ± 0.19	3.05 ± 0.02	3.60 ± 0.08	2.60 ± 0.05
Tail	2.25 ± 0.36	2.80 ± 0.07	3.70 ± 0.09	2.20 ± 0.03
Total	10.24 ± 0.69	14.50 ± 0.23	18.05 ± 0.14	10.80 ± 0.50
Single	9.90 ± 0.45	13.70 ± 0.30	19.15 ± 2.61	11.90 ± 0.34
Average	10.04 ± 2.85	14.10 ± 1.30	18.69 ± 7.17	11.34 ± 2.05

The low score meant the greater the deterioration in cover and the higher meant no damage

Appendix 22

Changes in corticosterone level in the plasma related to the feeder length stress. Samples obtained from 15 laying hens for each group. Hormone concentration expressed as means ± standard error.

Feeder length types		Corticosterone level (ng/ml)	MS	F
10 cm/hen	I-cage	2.68 ± 0.08 *a*	1.202	6.67 **
12 cm/hen	II-cage	2.05 ± 0.01 *b*		
12,5 cm/hen	III-cage	2.07 ± 0.03 *c*		
13,3 cm/hen	IV-cage	2.85 ± 0.2 *da*		

Means followed by different italic letters are statistically different with significance level $p < 0.05$.

** $p < 0.01$